Multistressors Related to Climate Change and Their Effects on Global Biodiversity during the Cenozoic Age

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Abstract

As multistressors have been shown to have significant effects on biodiversity and ecosystem functioning, the following study was made with the purpose of examining how a number of stressors specifically connected to climate change may have varied during the latest 65,5 million years and whether it is possible to predict potential effects on global biodiversity in the future. The analyses focused on global species richness during the Cenozoic age along with variables such as variations in atmospheric CO_2, sea surface temperatures and global sea levels derived from analyses of various stable isotopes found in marine sediments. The results were primarily based on a *Pearson Correlation Test* and a *One-Sample T-test*, including data from *Fossilworks.org* and from an empirical literature study. Two of the variables, sea surface temperature and global sea level, had a significant relationship to global species richness. Variations in atmospheric CO_2 were non-significant to species richness. The results suggest that multistressors related to various tectonic events, here expressed as changes in the oceanic circulation and the global mean temperature as a result of tectonic movements of the continents over time, had a higher impact on global biodiversity compared to stressors induced by changes in concentrations of CO_2 in the atmosphere during the Cenozoic age, based on the time-scale used in this study. However, given the fact that the time-scale used here was measured in millions of years rather than hundreds of thousands of years, those results might be slightly difficult to compare directly to similar effects in the present and thus predict potential future effects on global biodiversity. Based on those results, it is suggested that changes in concentrations of atmospheric CO_2 over time result in stress-related short-term effects on global biodiversity compared to other stressors induced by tectonic activity, although the former may still have some potential to affect global biodiversity in critical situations.

Contents

Introduction

Background

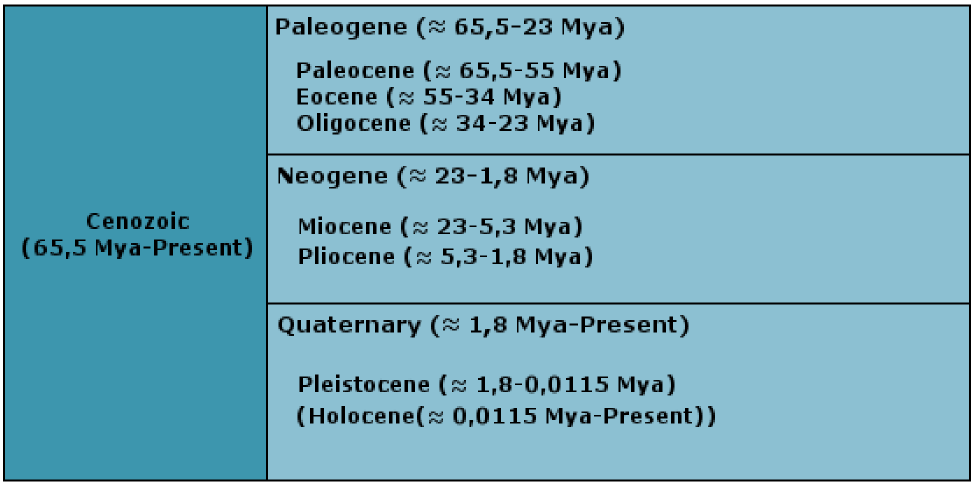
Ecosystems and organisms since the dawn of time constantly have been subjected to various stress effects, which could be defined as "any environmental factor that induces stress and thus may have an impact on population growth expressed in the form of reduced survival or reproduction relative to optimum conditions" (Folt et al., 1999). A stressor is usually defined as a variable of either abiotic or biotic origin exceeding its range of normal variation, which in turn could be expressed in the form of statistically significant effects in individual organisms or even entire populations. Such effects could in turn be expressed in the form of changes in biodiversity and ecosystem functioning, which may result in decreased resilience within a certain group or community of organisms depending on their vulnerability to changes as well as their organizational level (Vinebrooke et al., 2004). Examples of stressors affecting populations and ecosystems include both natural (e.g. competition, natural disturbance and predation) and even anthropogenic factors (such as exposure to xenobiotic contaminants released from human activity (Christensen et al., 2006; Heathwaite, 2010)). Additionally, stressors do not usually operate independently, resulting in the collectively combined impacts on biota defined as *multistressors* (Vinebrooke et al., 2004). Examples of multistressors in the natural environment include stressors induced by climate change such as increasing global temperatures (as a result of changes in the natural concentrations of atmospheric greenhouse gases (including carbon dioxide (CO_2)) in the atmosphere), the subsequent meltdown of the Arctic (Greene et al., 2008) and the Antarctic ice caps (Davies et al., 2012) and even increased acidification in the oceans (Guinotte & Fabry, 2008; Doney et al., 2009). Those multistressors have in turn been shown to have notable impacts on many organisms in marine ecosystems, of which the majority are playing vital roles in the global cycling of carbon, nitrogen and other elements essential for life on Earth (Brierley & Kingsford, 2009). This brings up the question of how multistressors connected to climate change and their impact may vary on entire ecosystems on a spatiotemporal scale, based on studies focusing on changes in species composition within a given area over time. As shown in previous studies, many groups of living organisms (ranging from corals in oceanic reefs to large mammals either roaming on land or dwelling in the oceans) are all more or less affected by climate change (Marx & Uhen, 2010; Hughes & Connell, 1999; Pyenson & Vermeij, 2016; Prothero, 2014), which in some notable cases have resulted in either various evolutionary adaptations to new environments induced by changes in the global climate regime, emigration to more suitable habitats or in some other cases their decline or even extinction (Costeur et al., 2004; Blois & Hadly, 2009; Moritz & Agudo, 2013).

The following literature study will be made with the purpose of examining how multistressors connected to climate change affect biodiversity on planet Earth over time on a planetary scale (Poloczanska et al., 2007), based on a comparison of data from the past during the Cenozoic age (dated back to the past 65,5 million years before Present Day (Dorf, 1960)).
An evaluation of the data will also be made to see whether it is possible to predict how global biodiversity may change in the future as a result of the increased number of multistressors indirectly induced by increased human activity. The investigation will be based on oceanographic, atmospheric as well as paleontological data from the Cenozoic era.

The Cenozoic Age

The Cenozoic age (also known as *the Age of Mammals*) is traditionally divided in the Paleogene, the Neogene and the Quaternary periods (see *Table 1* below), where the Paleogene comprises the three geological epochs known as the Paleocene, the Eocene and the Oligocene, the Neogene is divided in two epochs known as the Miocene and the Pliocene and the Quaternary comprises the Pleistocene (Crespo & Mansino, 2018) and the Holocene epoch (UCMP, 2018a).

Table 1: Table displaying the various periods defining the Cenozoic age, comprising the different epochs described below.



Cenozoic (65,5 Mya-Present)	**Paleogene (≈ 65,5-23 Mya)** **Paleocene (≈ 65,5-55 Mya)** **Eocene (≈ 55-34 Mya)** **Oligocene (≈ 34-23 Mya)**
	Neogene (≈ 23-1,8 Mya) **Miocene (≈ 23-5,3 Mya)** **Pliocene (≈ 5,3-1,8 Mya)**
	Quaternary (≈ 1,8 Mya-Present) **Pleistocene (≈ 1,8-0,0115 Mya)** **(Holocene(≈ 0,0115 Mya-Present))**

Below follows a series of brief descriptions for each of the six first epochs used in following study.

The Paleocene (≈ 65,5-55 Mya)

The non-avian dinosaurs (*Dinosauria*) and other large-bodied taxa had gone extinct at the Cretaceous-Tertiary Boundary approximately 65,5 million years ago (Mya) (Saarinen et al., 2014). The surviving mammals (*Mammalia*) subsequently dispersed all over the world (Zachos et al., 2001), filling in the ecological void left behind by the former clades of animals, which allowed them to adapt to all kinds of habitats previously occupied by the dinosaurs and other large creatures during the previous Mesozoic era (Blois & Hadly, 2009; Lovegrove & Mowoe, 2013; Yu et al., 2012). The terrestrial environment was entirely dominated by deciduous and tropical forests, and there were no savannahs or any other types of grasslands during this epoch (Lovegrove & Mowoe, 2013). Planet Earth was a "hot-house" (Markwick et al., 2000), characterized by a much higher global mean temperature compared to today, which in turn reached its peak during *the Paleocene-Eocene Thermal Maximum* (taking place around 55,5 Mya near the end of this epoch) (Foster et al., 2013). The event eventually led to the extinction of numerous deep-sea benthic foraminifera and a major turnover in mammalian diversity on land as a consequence of a disruption in both the oceanic and atmospheric circulation, marking the start of the Eocene (New World Encyclopedia, 2008; Self-Trail et al., 2017).

The Eocene (≈ 55-34 Mya)

Similar to the Paleocene, and prior *the Eocene-Oligocene Transition Event* which took place at the end of this epoch approximately 34 Mya (Zanazzi et al., 2007), the Eocene was influenced by generally high global mean temperatures (Weber & Thomas, 2017), which also reached their peak during *the Eocene Thermal Maximum* taking place approximately 53,2 Mya (D'haenens et al., 2014). Along with the appearance and diversification of many modern groups of organisms such as mammals (including whales (*Cetacea*)) and molluscs (*Mollusca*) (Encyclopædia Britannica, 2018a; Thewissen et al., 2009; Thewissen & Williams, 2002; Woodburne et al., 2009), the Eocene was also characterized by higher sea levels and poles with little or no ice (Zachos et al., 2008), and there were land connections between some of the continents, with the most important example being the land bridge which connected Antarctica to Australia before their separation as a result of plate boundary arrangement during the middle of this epoch (UCMP, 2018b). This event in turn resulted in a deep-water passage between the two continents, followed by the creation of the circum-Antarctic current, which later would subsequently alter the oceanic circulation and the global heat transport, causing a global cooling event (UCMP, 2018b). The change in global heat transport was then followed by the rapid cooling and the later glaciation of Antarctica which would mark the beginning of the next-coming epoch – the Oligocene (De Boer et al., 2010; Holdgate et al., 2017; Lear, et al., 2000: Hauptvogel, 2015; Pound & Salzmann, 2017).

The Oligocene (≈ 34-23 Mya)

As a response to the lower temperatures and the global reduction of forests on the continents (with one of the most notable examples being Australia (Martin, 2006)) at the end of the Eocene resulted by the effects caused by the change in global oceanic circulation, many species started adapting to the increasingly open savannahs during the Oligocene (Lovegrove & Mowoe, 2013; Smith et al., 2010). Those biomes would come to dominate in the terrestrial landscape during this epoch (UCMP, 2018b; 2018c). As the expansion of savannahs, prairies and other similar habitats proceeded in the terrestrial environment, most of the remaining forests gradually became more restricted to the warmer areas located around the equator at that time, and the most megathermal types of vegetation confined at the center of the area (Bush et al., 2011; UCMP, 2018c). At the same time, the increasingly colder climate (Walliser et al., 2017) also resulted in a worldwide reduction of diversity in marine plankton in the oceans near the end of the Oligocene, leading to a decline of other marine species as well due to the formers' role as the foundation of the food chain (UCMP, 2018c; Renaudie, 2016).

The Miocene (≈ 23-5,3 Mya)

Similar to the Oligocene, the Miocene was characterized by the global radiation of grasslands, as suggested by a globally higher occurrence of C_4 in fossil plants and herbivore tooth enamel from this epoch (Cerling et al., 1997; MacFadden, 2000; Domingo et al., 2009). Along with the expansion of grasslands during the Miocene followed the expansions of deserts, tundra and other similar vegetation systems (UCMP, 2018d) from the increasingly colder and more arid climate at that time (Bowman et al., 2017). Although the Miocene would come to be mostly recognized by a notable decrease in global mean temperature, this epoch also saw a brief event of global warming followed by a cooling shortly thereafter. This event has been considered responsible for the retreat of tropical ecosystems along with the expansion of coniferous forests in the northern hemisphere and an increase in global seasonality (UCMP, 2018d). While many groups of archaic mammals had gone extinct by the end of the preceding Oligocene (Blois & Hadly, 2009; Lovegrove & Mowoe, 2013; Smith et al., 2010; Tomiya, 2013; Encyclopædia Britannica, 2018b), the remaining families of mammals had now started to develop many new forms, of which several still exist today (The NOW Community, 2003). After having recovered from the preceded turnover that took place at the end of the Oligocene (Prothero, 2004), the new changes in the oceanic nutrient circulation as a result of another event of plate boundary rearrangements then led to an increase in productivity in some areas in the oceans, enabling an increase in biodiversity even among plankton and molluscs followed by the appearance of the first kelp forests (Edinger, 1991; UCMP, 2018d; Bolton & Stoll, 2013; Encyclopædia Britannica, 2018b). The occurrence of land bridges connecting Africa to Eurasia (UCMP, 2018c; Costeur et al., 2004; Madern & Van den Hoek Ostende, 2015; Bobe, 2006) and Eurasia to North America (UCMP, 2018d) also enabled interchanges of terrestrial species between those continents while Australia and South America would remain isolated until the on-coming Pliocene, when South America later on would be connected to North America as a result of the Panamanian land-bridge, which occurred during this epoch (UCMP, 2018e).

The Pliocene (≈ 5,3-1,8 Mya)

The Pliocene could at best be described as a time of global cooling (Encyclopædia Britannica, 2018c; UCMP, 2018e) from the raising of the Himalayas and other mountainous areas near the end of the earlier Miocene (Bradshaw et al., 2012). The event has been theorized as one of many possible factors that might have accelerated the cooling process due to the chilling effect montane areas normally tend to have on the global climate in general (UCMP, 2018e). The event of global cooling now also caused grasslands and savannahs to spread even on the continents during the Pliocene, which in turn favored the evolution and diversification of grazing herbivores, albeit at the expense of certain browsing species living during the same time (UCMP, 2018e). The expanded glaciation of Antarctica along with the formation of sea ice in the Arctic would give way to a global cooling trend continuing up to the next epoch – the Pleistocene (UCMP, 2018e; 2018f).

The Pleistocene (≈ 1,8-0,0115 Mya)

As the global mean temperature continued to drop, this event enabled the expansions of both the Arctic and Antarctic ice caps in both hemispheres, causing much of the temperate zones found in especially the northern hemisphere to be covered by glaciers during the cooler periods commonly known as the ice ages, which temporarily retreated only during the comparably warmer interglacial periods during this epoch (UCMP, 2018f). The Pleistocene was also characterized by biotas very close to modern ones, of which many genera and species have managed to survive to this day (UCMP, 2018f). The epoch was also distinguished by the presence of notably large species of birds and mammals found on all continents, before most of them eventually went extinct during the latest ice age, which took place approximately 11500 years ago (UCMP, 2018f).

Aim

The purpose of this study is to address the question how multistressors and their connections to climate change have been approached in previous studies, and how this knowledge could potentially be used to predict the future effects of the on-going global warming. The investigation will be based on the measured global biodiversity in marine, terrestrial and limnologic environments during the Cenozoic Age (≈ 65,5-0,0115 Mya). Questions relevant for this study are as follows:

- Are there any significant relationships between multistressors inducing climate change and global biodiversity, and how could those relationships possibly be explained?
- If such relationships do exist, how have the relationships varied over the past 65,5 million years and why?
- Is it possible, based on the results from the analysis, to predict changes in global biodiversity even in the future?

Restrictions

This study will focus on multistressors induced by variations of levels of CO_2 in the atmosphere which have been shown having significant impacts on the global environment (Foster et al., 2017; Schmidt, 2018; Nikolov & Zeller, 2011). Other stressors related to variations in ocean temperatures and global sea level, which both show a tendency of being influenced by geological factors including changes in the global oceanic circulation, which is indirectly induced by the tectonic movements of the continents over time, will be included in this study as well.

Methodology

The paleontological data was retrieved from the digital database known as *Fossilworks.org* (http://fossilworks.org/bridge.pl) through a series of extensive searches for all scientifically known species living during the Cenozoic age registered at the database (divided into the six previously described geological epochs known as the *Paleocene*, the *Eocene*, the *Oligocene*, the *Miocene*, the *Pliocene* and the *Pleistocene*; which following study in turn is focusing on). The database assembles paleontological data from all around the world, is updated regularly and also works as a gateway to another database known as the *Paleobiology Database*, which provides more precise information about the fossil findings collected at *Fossilworks.org*. However, as this study is solely restricted to focus on the total numbers of scientifically known species living during each of the six previous epochs, *Fossilworks.org* was the only database that was used.

All numbers of identified species for each organism group living during each of the six chosen Cenozoic epochs found in the database were plotted in an *Excel*-sheet (see *Appendix 1a & 1b*), and the total numbers of species from all organism groups along with the equivalent values for the *species richness* (*H'*) using *Shannon-Wiener's Diversity Index* for each epoch were then calculated (see *Appendix 1b*). The diversity index was chosen based on its ability to weight all species found within a certain area equally regardless their ecological and morphological properties or rarity in the fossil record, as well as on the fact that this index has been shown to present better statistical resolution compared to most other diversity indices (Costeur et al., 2004; Mårtensson, 2016). To simplify the search for relevant species data at *Fossilworks.org*, each search was made one taxon combined with one epoch at the time for each of the six chosen time periods and the output data format used in all searches was solely based on the number of *specimens*, while the taxonomic level applied to each search was based on the number of *species* over the number of *genera* (as this study is solely focused on the taxonomic level). Those settings were the only ones that were used without any alterations throughout the entire search for data at *Fossilworks.org*, along with the chosen *output delimiter*, for which the option making the retrieved results to be expressed in the form of species lists of *comma-delimited text* was in this case chosen in order to obtain more easily foreseeable lists based on the number of *ranges* for each chosen group of fossil organisms living during a certain geological epoch.

Each search performed at *Fossilworks.org* was restricted by certain keyword options used in the database (see *Appendix 1c*), which in turn are based on what types of *Research Groups or Research Projects* each group of fossil organisms are most likely based on or restricted to (see *Appendix 1d*). While the search for occurrences of species living during the various Cenozoic epochs including mammals (*Mammalia*), birds (*Aves*), reptiles (*Reptilia*), amphibians (*Amphibia*), ray-finned fishes (*Actinopterygii*) and cartilaginous fishes (*Chondrichthyes*) were all based on the keyword "*vertebrate*", the search for occurrences of other fossil organisms from the same era were based on other keywords used at *Fossilworks.org*. In the case of some other organism groups such as echinoderms (*Echinodermata*) and sac fungi (*Ascomycota*), the keywords "*marine invertebrate*" and "*mid-Pz*", respectively, were used instead, while the keyword "*paleoentomology*" turned out to be applicable not only for insects (*Insecta*), but also (oddly enough) for other types of fossil arthropods as well, including arachnids (*Arachnida*) and millipedes (with the latter group belonging to the subphylum *Myriapoda*). Akin to some of the previously mentioned examples above, the searches for occurrences of various types of fossil plants (including flowering plants (*Angiospermae*), conifers (*Pinophyta*), cycads (*Cycadophyta*), ferns (*Pteridophyta*) and mosses (*Bryophyta*)) were based on the word "*paleobotany*", while the searches for occurrences of various types of fossil kelp and algae (all belonging to the widely heterogeneous clade known as *Archaeplastida*) were based on a combination of the keywords "*paleobotany*" and "*micropaleontology*", rather than on a single keyword unlike most other searches performed at the database. At the same time, it also turned out that the keywords "*marine invertebrate*" and "*freshwater*" were both applicable for many different groups of mostly marine invertebrates such as cephalopods (*Cephalopoda*), gastropods (*Gastropoda*), bivalves (*Bivalvia*), brachiopods (*Brachiopoda*), crustaceans (*Crustacea*), annelids (*Annelida*), hydrozoans (*Hydrozoa*) and even other groups such as sea anemones and corals (both belonging to the class known as *Anthozoa*); although it (oddly enough) appeared that the word "*freshwater*" somehow tended to yield notably more taxonomic occurrences (expressed in *ranges*) for those groups of organisms rather than the keyword "*marine invertebrate*", covering species found in both limnologic as well as in marine environments for some reason.

An empirical literature search using *the Snowball Technique* was performed to obtain estimated values for the concentrations of CO_2 in the atmosphere (pCO_2) during each of the six chosen Cenozoic epochs along with other data for the equivalent variations in global deep ocean (T_{DO}) and sea surface (T_S)

temperatures and sea levels (SL) (Leinfelder & Seyfried, 1993) from the same epochs (with all three derived from various deep-sea isotope records of Cenozoic ocean sediments (Cermeño et al., 2013; Alroy et al., 2000). The data for the concentrations was retrieved from the *Supplementary Information* of an article written by Royer (2006), which cites data derived from various other articles (see *Appendix 2*), including estimated concentrations of atmospheric CO_2 (ppm) and what methods that have been used in order to determine values for those concentrations along with the age of a certain concentration. Examples of such methods that had in this case been used to determine the various CO_2 concentrations during various prehistoric time periods included proxy-methods such as the determination of the species composition of microfossils of phytoplankton and foraminifera found in ancient marine sediments (Stott, 1992; Pagani et al., 1999a; 1999b; 2005; Freeman & Hayes, 1992; Andréasson, 2011; Cermeño et al., 2015: Hannisdal et al., 2017; Aze et al., 2011) along with analyses of stable carbon isotopes in paleosols such as $\delta^{13}C$ (Ekart et al., 1999; Yapp & Poths, 1996; Cerling, 1992; Yapp, 2004; Royer et al., 2001; Sinha & Stott, 1994; Koch et al., 1992; Nordt et al., 2002; 2003; Ishimura et al., 2012; Andréasson, 2011), which both can provide valuable information about the global climate during prehistoric time (Andréasson, 2011; Lowenstein & Demicco, 2006; Bowen et al., 2006; Tipple et al., 2010), including e.g. variations in pCO_2 and their potential effects on the global mean temperature. Given that this report is focusing on the Cenozoic age, only data ranging from 65,5 Mya to 100000 years ago was selected from the various articles referenced by Royer (2006), resulting in 308 data points for the later analysis which also would set the standard for the total number of data points used for the other variables used in this study.

The proxy-data for the Cenozoic variations in global deep-ocean and sea surface temperatures as well as for sea levels from the same epochs (see *Appendix 3a*) were retrieved from the *Supplementary Information* belonging to Hansen et al. (2013) (which in turn is derived from data retrieved from a *5-Point Running Mean* by Zachos et al. (2008)). The data are based on various analyses of the relationship between the two stable oxygen isotopes ^{18}O and ^{16}O (also known as $\delta^{18}O$) (Andréasson, 2011) in the shells of fossilized deep-sea benthic foraminifera found in marine sediments, which in turn are based on various records from the *Deep Sea Drilling Project* and the *Ocean Drilling Program* (Zachos et al., 2008; Zachos et al., 2001; Lisiecki & Raymo, 2005; Sexton et al., 2006; Zachos et al., 1994; Heath, 1984). By studying the relationship between oxygen isotopes, it is possible to determine water temperatures (T_{DO} & T_S), sea level (SL) and in some cases even the total volumes of ice on the continents during the time when the foraminifera were alive (Hansen et al., 2013; Alroy et al., 2000; Thomas & Dieckmann, 2008; Hauptvogel et al., 2017; Andréasson, 2011; Mudelsee et al., 2014; Zeebe, 2001).

The data found in the *Supplementary Information* belonging to Hansen et al. (2013) initially turned out to include a far more extensive amount of data points within the same time span compared to the ones derived from the various articles referenced by Royer (2006), the majority of the data points for the variations in global deep ocean and sea surface temperatures and sea levels therefore were recalculated into average values compatible with the time series previously established by the various articles referenced by Royer (2006). Average values for the chosen variables were then calculated for each Cenozoic epoch (see *Appendix 2 & 3b*) in order to make them better fit with the previously values for species richness prior the analysis of those values along with the values for species richness.

Those values are shown in *Table 2* below.

Table 2: Table displaying the values of Cenozoic species richness (*H'*) for each epoch along with the calculated average values for atmospheric CO_2 (*pCO_2*; ppm), global deep-ocean temperature (T_{DO}; °C), sea surface temperature (T_S; °C) as well as for global sea level (SL; m) for the same epochs as well.

Epoch	**Species Richness (*H'*)**	***pCO_2* (ppm)**	T_{DO} (°C)	T_S (°C)	**SL (m)**
Paleocene	3,1096	578	9,66	24,8	65,0
Eocene	3,2194	792	8,71	23,9	64,6
Oligocene	3,0468	504	4,09	19,2	46,4
Miocene	3,2144	262	3,54	18,7	37,7
Pliocene	0,9078	405	1,29	15,4	0,552
Pleistocene	0,8399	326	-0,015	12,2	-50,8

The analysis was performed using the software program *IBM SPSS Statistics 24*. Given that the purpose of this project was to see whether if there are significant relationships between any of the variables, as well as if there possibly are some *2-Tailed* significant relationships within the same variables over time, a *Pearson Correlation Test* along with a *One-Sample T-test*, respectively (given the fact that most of the data consisted of average values in this case (Grandin & Swedish Environmental Protection Agency, 2003)), were performed. Following statistical tests both included the values of species richness calculated for each of the six Cenozoic epochs as well as the corresponding calculated average values of global deep-ocean temperature (°C), sea surface temperature (°C), sea level (m) along with the estimated average concentrations of atmospheric CO_2 (ppm) during the same epochs.

In order to test the robustness of the results from both of those tests, a *bootstrapping* based on 1000 iterations was also performed for each of the tests during the analysis, followed by a *Generalized Linear Models Test* to test those variables for which significant *p-values* were found in this case, based on the results from the previous *Pearson Correlation Test*.

Results

Cenozoic species richness (*Figure 1*) has a significant relationship to both sea surface temperature (p= 0,034) and sea level (p = 0,012) (*Pearson Correlation Test* (*Table 3*)). At the same time, sea surface temperature and sea level have a significant relationship to each other (p = 0,004), while deep ocean temperature has significant relationships to both variables (p = 0,000 & p = 0,020, respectively). Global deep ocean temperature has no significant relationship to global species richness (p = 0,067), which also is shown in *Table 3* below.

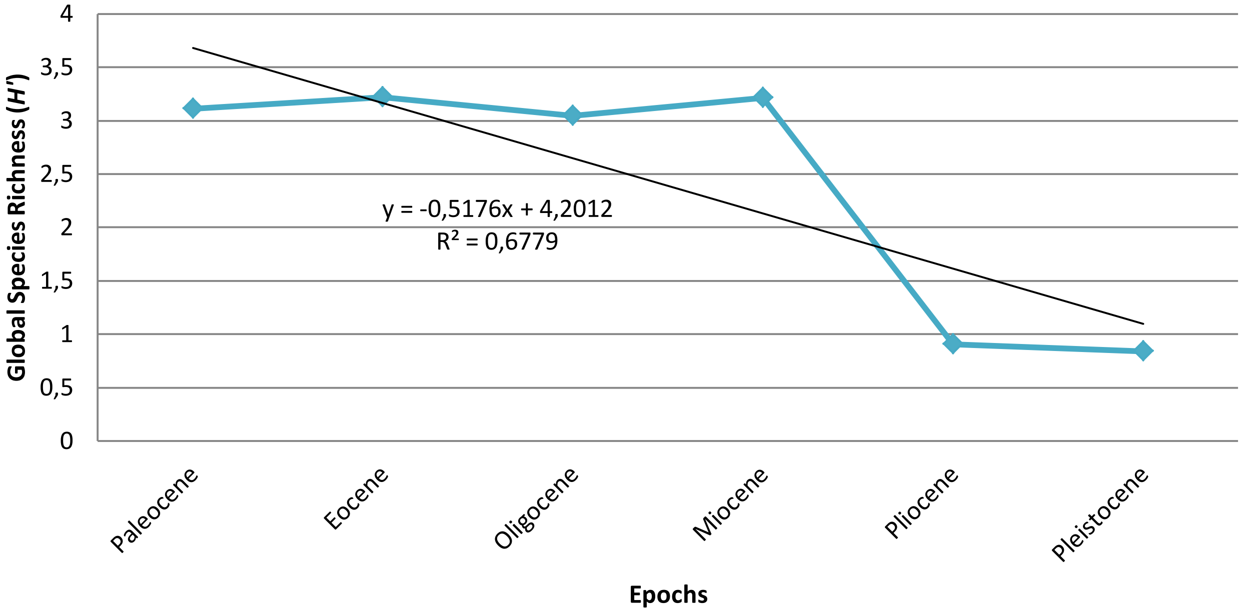


Figure 1: Global species richness through the Cenozoic age.

Table 3: Table displaying all the *2-Tailed p-values* retrieved from the previous *Pearson Correlation Test*. The squares marked in blue indicate insignificant *p-values* ($p > 0,05$), meaning that there are no significant relationships between the corresponding variables, while the white ones indicate significance between other variables in the same table.

	Species Richness (H')	**pCO_2 (ppm)**	**Deep Ocean Temp. (T_{DO})**	**Sea Surface Temp. (T_S)**	**Sea Level (m)**
Species Richness (H')	-	0,364	0,067	0,034	0,012
pCO_2 (ppm)	0,364	-	0,062	0,086	0,173
Deep Ocean Temp. (T_{DO})	0,067	0,062	-	0,000	0,020
Sea Surface Temp. (T_S)	0,034	0,086	0,000	-	0,004
Sea Level (m)	0,012	0,173	0,020	0,004	-

Figure 2 (see *Appendix 4*) shows that global seasurface temperature (T_S; shown in the upper graph) and deep ocean temperature (T_{DO}; shown in the lower graph) have varied during the Cenozoic age. While there is no significant trend for global deep ocean temperature over time (based on the results from the *One-Sample T-test* shown in *Table 4* below), following graph still appears to have a significant relationship to the graph for global surface temperature, as suggested by both their similarities in shape along with their notably high determination coefficients (R^2). It is also suggested that while deep ocean temperature does not have any significant relationship to global species richness, changes in the global sea surface temperature appears to have had significant effects on global species richness during the Cenozoic era instead (*Table 3*). While there is no significant trend for the global sea level during the Cenozoic age (based on the results shown in *Table 4* below), this variable (*Figure 3; Appendix 4*) is still shown to have significant relationships to global species richness during the same era as well as to both sea surface temperature and deep ocean temperature (based on the results of the previous *Pearson Correlation Test* in *Table 3*). The *One-Sample T-test* (*Table 4*), which also included a *Bootstrap Iteration* to test the robustness of the results from this test showed that while there apparently are no significant trends for Cenozoic species richness ($p = 0,085$), deep ocean temperature ($p = 0,068$) or sea level ($p = 0,246$) over time. The results of the test also revealed that there are significant trends for both concentrations of atmospheric CO_2 ($p = 0,003$) and sea surface temperature ($p = 0,002$) over time, in spite of the results from the *Pearson Correlation Test*, which revealed that the former of those two variables has no significant relationships to any of the other variables applied to this test.

Table 4: The p-values from the *One-Sample T-test*. The squares marked in blue indicate insignificant p-values ($p > 0{,}05$), meaning that there are no significant trends for the corresponding variables over time, while the white ones indicate significant trends for other variables in the same table.

Variables	**p-Value**
Species Richness	0,085
pCO_2 (ppm)	0,003
Deep Ocean Temp. (T_{DO})	0,068
Sea Surface Temp. (T_S)	0,002
Sea Level (m)	0,246

The concentrations of atmospheric CO_2 is shown to have no significant relationship to any of the other variables in this case (including species richness (*Pearson Correlation Test* (*Table 3*)), given that the p-values measuring the 2-Tailed significance for those variables in comparison to the concentrations of CO_2 in the atmosphere turned out to exceed 5 % ($p > 0{,}05$) in all those cases. The result could be explained by the fluctuations of concentrations of atmospheric CO_2 over time along with the low determination coefficient ($R^2 = 0{,}1352$) also shown in *Figure 4* (see *Appendix 4*).

However, while this variable shows no significant relationship at all to any of the other variables according to the *Pearson Correlation Test*, the result of the *One-Sample T-test* does still suggest that there still is a significant trend for this variable over time, as shown in *Table 4* above.

Discussion

Variations in global sea surface temperature and changes in global sea level were significantly correlated to global species richness during the Cenozoic era. Sea surface temperature was the only one of those two variables to display a significant trend over time (based on the results retrieved from the *One-Sample T-test* in this case). Climate change expressed in the form of changes in global sea surface temperature and sea level could be seen as having the most significant impacts on global biodiversity during the Cenozoic age as well as on the evolutionary dynamics of certain groups of organisms including mammals during the same era (Finarelli & Badgley, 2010; Figueirido et al., 2012). Based on the obtained results of this study, it is suggested that tectonic movements of the continents have indirect impacts on ocean currents, temperature and on the global circulation of essential elements such as carbon (John et al., 2013), which in turn might have had impacts on global biodiversity during the Cenozoic as well. As previously described in the *Introduction* of this study, one example includes the fact that changes in the global mean temperature (here expressed as changes in global sea surface temperature) seem to occasionally have coincided with certain events of extinction and faunal turnover during following era, with some of the most notable examples being both the extinction of several deep-sea benthic foraminifera and the turnover of terrestrial mammals during *the Paleocene-Eocene Thermal Maximum* near the end of the Paleocene around 55,5 Mya (Foster et al., 2013; New World Encyclopedia, 2008; Self-Trail et al., 2017) as well as the major reduction of marine organisms during the increasingly colder Oligocene (Walliser et al., 2017; UCMP, 2018c; Renaudie, 2016), of which the latter event subsequently may have caused the faunal turnover as a result of the previously described changes in primary productivity; based on the previously described reduction of diversity in marine plankton during following epoch in this case along with their recovery during the Miocene (UCMP, 2018c; 2018d; Bunt, 1975). Another example of effects on global biodiversity as a result of continental movements also includes including the separation of Australia and Antarctica during the Middle Eocene (UCMP, 2018b). This example in turn has previously been theorized as causing the first episode of global cooling during the Cenozoic era due to the deep-water passage that was created between the two continents at that time (UCMP, 2018b). Following fact might explain why the tropical forests (which are commonly known to have the highest species diversity of all habitats found in the terrestrial environment (Bush et al., 2011)) started to slowly retreat to the warmer areas located around the equator at the same time as the grasslands started to expand in the terrestrial environment along with the rapid cooling of Antarctica during the next-coming Oligocene (UCMP, 2018c; Bush et al., 2011), causing some species to develop certain adaptations necessary to survive in the new, open habitats in the terrestrial landscape (Lovegrove & Mowoe, 2013; Smith et al., 2010). Given that oceanic stratification, which is defined as the mixing of nutrients induced by barriers between water masses with different chemo-physical properties such as salinity, oxygenation and density, is also depending on temperature (Valiela, 1984), this drop in global mean temperature may in turn have contributed to drastic changes in oceanic circulation during the Oligocene as well, which in turn would come to influence the global climate during the on-coming Miocene, as well as during the Pliocene and the Pleistocene (UCMP, 2018d; 2018e; 2018f). Those effects on the global climate during those epochs are evidentally supported by the further radiation of grasslands along with the increased diversity of species more or less adapted to such habitats (UCMP, 2018d; 2018e; 2018f; Cerling et al., 1997; The NOW Community, 2003). Other examples of effects on global biodiversity caused by continental movements during the Cenozoic may also have included the occurrence of land bridges between continents (as a result of the subsequent lowering in global sea level due to the glaciation and accumulation of sea water on Antarctica and in the Arctic) (Costeur et al., 2004; Bobe, 2006) and the formation of mountainous areas during the Miocene and the Pliocene, of which the latter for example has been shown to indirectly increase the diversification within populations of species through isolation, enabling the evolution of more species over time (UCMP, 2018d; 2018e).

It is important to remember, however, that while global changes induced by tectonic movements also do seem to have indirect effects on ocean circulation and thus on nutrient fluxes, including the global sequestering of carbon, those changes still operate on geological timescales (> 10^5 years) rather than on biological timescales (< 10^5 years). Given that biological changes in those fluxes most of the time only have strongly acute effects on the global environment and thus have disruptive effects on the climate balance only in critical situations (Spicer, 1993). While both sea surface temperature and global sea level did appear to have significant relationships to deep-ocean temperature (also based on the results from the *Pearson Correlation Test*), the latter variable was instead shown to have no significant relationship to global species richness at all, unlike the two former variables in this case. The results indicate that changes in global deep-ocean temperature did not have much impact on the global biodiversity during the Cenozoic; supported by the results from the *One-Sample T-test* which revealed that there is no significant trend for this variable over time either, in spite of the fact that the global deep-ocean temperature does have decreased over the latest 65,5 million years under the apparent influence of changes in both the aforementioned sea surface temperature and global sea level during the geological era.

In the case of the concentrations of atmospheric CO_2, the variable was shown to have no significant relationship to any of the other variables (including species richness), based on the results obtained from the *Pearson Correlation Test*, even though the results from the *One-Sample T-test* did show that there still is a significant trend for the variations in atmospheric CO_2 concentrations over time. Those results could be explained by the fact that the different values for the Cenozoic CO_2 concentrations in the atmosphere that were applied to those tests are all based on various proxy-methods, suggesting that all p-values from the analysis are more or less depending on the reliability of each of the chosen proxy-methods in this case. The proxy-methods that were used in order to obtain the CO_2-data used in following study include analyses of paleosols (Yapp & Poths, 1996; Cerling, 1992; Royer et al., 2001; Sinha & Stott, 1994; Ishimura et al., 2012), estimations regarding species compositions of fossilized foraminifera and phytoplankton found in marine sediments (Stott, 1992; Pagani et al., 1999a; 1999b; 2005; Freeman & Hayes, 1992), determinations of prehistoric levels of atmospheric CO_2 based on leaf stomatal frequencies in either living or fossilized plants (Beerling et al., 2002; Royer, 2003; Kürschner et al., 2001; Greenwood et al., 2003) as well as estimations regarding occurrences of the stable boron-isotope ^{11}B in marine sediments, which works as a marker upon estimations of atmospheric CO_2 concentrations in the past (Demicco et al., 2003).

Potential sources of error in this study may also include the differences in time duration regarding the various Cenozoic epochs, which in turn might have had some impact on the results from the analysis; especially in the case of the calculated values of species richness for each epoch. Given that the values of species richness for each epoch are covering all species living during the same epoch and not during a certain timeline within the epoch, following bias combined with the previously described and somewhat irregular time interval suggests that more accurate results for Cenozoic species richness during the Paleocene, the Eocene, the Oligocene, the Miocene, the Pliocene and the Pleistocene might in this case have been obtained if there were more established time intervals for the global species richness within each of the listed epochs. As a result of time constraints combined with some limitations regarding the use of the database *Fossilworks.org* (which further only enables searches for species data based on certain time intervals known by name rather than by number), however, this study therefore is solely focusing on variations in global species richness between those epochs and their possible connections to climate change in this case. Based on the fact that the time-scale used in following study is measured in millions of years rather than hundreds of thousands of years, this also makes the effects of changes in for example global mean temperature, the concentrations of CO_2 in the atmosphere and global sea level during the Cenozoic age slightly difficult to compare directly with those in the present (and thus predict potential effects on global biodiversity in the future). Variations in atmospheric CO_2 concentrations in modern times have been shown to occur within a considerably shorter amount of time usually measured in centuries or even decades, most likely as a result of increased human activity (Lane, 2011). Given that the extent of data regarding the variations in atmospheric CO_2, global deep ocean and sea surface temperatures and global sea level in relation to global species richness in this case tends to vary considerably between the various epochs as a result of their differences in time duration along with the obtained number of data points for each epoch, this study could most likely be further improved if an equal amount of data points for each epoch had been applied to the analysis instead. Depending on the quality of those data points as well as on their statistical resolution compared to those that were actually used in this study, it is suggested that other results might possibly have been obtained in this case; also depending on the extent of available material for each epoch along with the amount of added resources regarding the research of the various epochs used in this study.

As summarized, multistressors indirectly induced by continental movements do seem to have considerably higher impacts on global biodiversity over time compared to other stressors specifically induced by variations in global concentrations of atmospheric CO_2, although the latter do still have some potential to affect global biodiversity at times when the CO_2 in the atmosphere reaches a certain threshold concentration, even though such events still mostly occur in especially critical situations.

Conclusion

Based on following study, multistressors related to tectonic events as well as changes in global oceanic circulation appeared to have higher impacts on global biodiversity during the Cenozoic age compared to other stressors specifically related to variations in atmospheric CO_2 concentrations. Although multistressors connected to continental movements appeared to be the only ones to have significant relationships to changes in global biodiversity, the result does not necessarily exclude the possibility that multistressors associated with variations in atmospheric CO_2 may have had effects on biodiversity as well, albeit within considerably shorter periods of time compared to stressors induced by tectonic events. However, given the fact that the time-scale used here was measured in millions of years rather than hundreds of thousands of years, those results might be slightly difficult to compare directly to similar effects in the present and thus predict potential future effects on global biodiversity.

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Appendices

Appendix 1a

Organism Group (*Scientific Name*)	**Organism Group (*Common Name*)**
Opisthokonta	Opisthokonts
Rhizaria	Cercozoa, Foraminifera & Radiolaria
Heterokontophyta	Heterokonts
Archaeplastida	Kelp & Algae
Marchantiophyta	Liverworts
Bryophyta	Mosses
Pteridophyta	Pteridophytes (aka Ferns)
Cycadophyta	Cycads
Pinophyta	Conifers
Angiospermae	Flowering Plants
Ascomycota	Sac Fungi
Calcarea	Calcareous Sponges
Hexactinellida	Glass Sponges
Hydrozoa	Hydrozoans
Anthozoa	Sea Anemones, Corals & Gorgonians
Platyhelminthes	Flatworms
Nematoda	Roundworms
Annelida	Annelids (aka Ringed Worms or Segmented Worms)
Onychophora	Velvet Worms
Myriapoda	Millipedes, Centipedes et al.
Arachnida	Arachnids
Crustacea	Crustaceans
Insecta	Insects
Bryozoa	Moss Animals
Brachiopoda	Brachiopods
Bivalvia	Bivalves

Gastropoda	Gastropods
Cephalopoda	Cephalopods
Polyplacophora	Chitons
Scaphopoda	Tusk Shells (aka Tooth Shells)
Echinodermata	Echinoderms
Craniata	Hagfishes
Chondrichthyes	Cartilaginous Fishes
Actinopterygii	Ray-Finned Fishes
Sarcopterygii	Fringe-Finned Fishes
Amphibia	Amphibians
Reptilia	Reptiles
Aves	Birds
Mammalia	Mammals

Appendix 1b

Organism Group (*Scientific Name*)	***Paleocene***	***Eocene***	***Oligocene***	***Miocene***	***Pliocene***	***Pleistocene***
Opisthokonta	52	154	82	164	-	-
Rhizaria	253	178	78	79	-	5
Heterokontophyta	11	-	-	-	-	-
Archaeplastida	11	7	1	12	2	1
Marchantiophyta	1	-	-	-	-	-
Bryophyta	11	1	1	3	-	1
Pteridophyta	137	116	60	56	17	4
Cycadophyta	3	7	5	3	-	-
Pinophyta	42	79	63	98	25	3
Angiospermae	42	41	27	68	30	-
Ascomycota	-	1	-	1	-	-
Calcarea	7	5	-	1	-	1
Hexactinellida	6	54	7	15	-	-
Hydrozoa	7	17	5	13	5	9
Anthozoa	291	822	673	1454	553	697
Platyhelminthes	-	1	-	-	-	-
Nematoda	-	25	1	51	1	-
Annelida	30	24	3	27	10	44
Onychophora	-	1	-	1	-	-
Myriapoda	-	40	2	22	2	-
Arachnida	-	1063	40	317	8	-
Crustacea	142	697	266	922	354	249
Insecta	249	7145	1566	3057	224	937
Bryozoa	183	465	275	760	375	279
Brachiopoda	70	165	43	132	44	47
Bivalvia	1278	3269	1627	5145	2962	2465
Gastropoda	2290	5735	1884	8488	5158	4797

Cephalopoda	78	132	19	23	-	2
Polyplacophora	-	24	6	16	19	30
Scaphopoda	48	115	61	152	103	43
Echinodermata	147	362	131	324	86	47
Craniata	4	3	-	7	1	-
Chondrichthyes	79	337	106	316	105	38
Actinopterygii	55	481	174	470	147	205
Sarcopterygii	3	2	1	3	1	1
Amphibia	24	35	34	98	16	92
Reptilia	189	612	205	523	119	286
Aves	36	159	83	257	183	665
Mammalia	1033	3502	1791	4164	1067	2075
Total Number of Species per Epoch	6812	25876	9320	27242	11617	13023
Species Richness (Shannon-Wiener = *H'*)	3,10963771	3,219425	3,0468038	3,214375	0,9078075	0,83989864

Appendix 1c

Organism Group (*Scientific Name*)	***Keyword(s) Used at Fossilworks.org***
Opisthokonta	*micropaleontology*
Rhizaria	*micropaleontology*
Heterokontophyta	*micropaleontology*
Archaeplastida	*paleobotany & micropaleontology*
Marchantiophyta	*paleobotany*
Bryophyta	*paleobotany*
Pteridophyta	*paleobotany*
Cycadophyta	*paleobotany*
Pinophyta	*paleobotany*
Angiospermae	*paleobotany*
Ascomycota	*mid-Pz*
Calcarea	*freshwater*
Hexactinellida	*freshwater*
Hydrozoa	*freshwater*
Anthozoa	*freshwater*
Platyhelminthes	*freshwater*
Nematoda	*freshwater*
Annelida	*freshwater*
Onychophora	*paleoentomology*
Myriapoda	*paleoentomology*
Arachnida	*paleoentomology*
Crustacea	*freshwater*
Insecta	*paleoentomology*
Bryozoa	*freshwater*
Brachiopoda	*freshwater*
Bivalvia	*freshwater*
Gastropoda	*freshwater*
Cephalopoda	*freshwater*
Polyplacophora	*freshwater*
Scaphopoda	*freshwater*
Echinodermata	*marine invertebrate*
Craniata	*vertebrate*

Chondrichthyes	*vertebrate*
Actinopterygii	*vertebrate*
Sarcopterygii	*vertebrate*
Amphibia	*vertebrate*
Reptilia	*vertebrate*
Aves	*vertebrate*
Mammalia	*vertebrate*

Appendix 1d

Organism Group (*Scientific Name*)	**Sources**
Opisthokonta	FossilWorks.org (2018a; 2018b; 2018c; 2018d)
Rhizaria	FossilWorks.org (2018e; 2018f; 2018g; 2018h; 2018i)
Heterokontophyta	FossilWorks.org (2018j)
Archaeplastida	FossilWorks.org (2018k; 2018l; 2018m; 2018n; 2018o; 2018p)
Marchantiophyta	FossilWorks.org (2018q)
Bryophyta	FossilWorks.org (2018r; 2018s; 2018t; 2018u; 2018v)
Pteridophyta	FossilWorks.org (2018w; 2018x; 2018y; 2018z; 2018aa; 2018ab)
Cycadophyta	FossilWorks.org (2018ac; 2018ad; 2018ae; 2018af)
Pinophyta	FossilWorks.org (2018ag; 2018ah; 2018ai; 2018aj; 2018ak; 2018al)
Angiospermae	FossilWorks.org (2018am; 2018an; 2018ao; 2018ap; 2018aq)
Ascomycota	FossilWorks.org (2018ar; 2018as)
Calcarea	FossilWorks.org (2018at; 2018au; 2018av; 2018aw)
Hexactinellida	FossilWorks.org (2018ax; 2018ay; 2018az; 2018ba)
Hydrozoa	FossilWorks.org (2018bb; 2018bc; 2018bd; 2018be; 2018df; 2018bg)
Anthozoa	FossilWorks.org (2018bh; 2018bi; 2018bj; 2018bk; 2018bl; 2018bm)
Platyhelminthes	FossilWorks.org (2018bn)
Nematoda	FossilWorks.org (2018bo; 2018bp; 2018bq; 2018br)
Annelida	FossilWorks.org (2018bs; 2018bt; 2018bu; 2018bv; 2018bw; 2018bx)
Onychophora	FossilWorks.org (2018by; 2018bz)
Myriapoda	FossilWorks.org (2018ca; 2018cb; 2018cc; 2018cd)
Arachnida	FossilWorks.org (2018ce; 2018cf; 2018cg; 2018ch)
Crustacea	FossilWorks.org (2018ci; 2018cj; 2018ck; 2018cl; 2018cm; 2018cn)
Insecta	FossilWorks.org (2018co; 2018cp; 2018cq; 2018cr; 2018cs; 2018ct)
Bryozoa	FossilWorks.org (2018cu; 2018cv; 2018cw; 2018cx; 2018cy; 2018cz)
Brachiopoda	FossilWorks.org (2018da; 2018db; 2018dc; 2018dd; 2018de; 2018df)
Bivalvia	FossilWorks.org (2018dg; 2018dh; 2018di; 2018dj; 2018dk; 2018dl)
Gastropoda	FossilWorks.org (2018dm; 2018dn; 2018do; 2018dp; 2018dq; 2018dr)
Cephalopoda	FossilWorks.org (2018ds; 2018dt; 2018du; 2018dv; 2018dw)
Polyplacophora	FossilWorks.org (2018dx; 2018dy; 2018dz; 2018ea; 2018eb)

Scaphopoda	FossilWorks.org (2018ec; 2018ed; 2018ee; 2018ef; 2018eg; 2018eh)
Echinodermata	FossilWorks.org (2018ei; 2018ej; 2018ek; 2018el; 2018em; 2018en)
Craniata	FossilWorks.org (2018eo; 2018ep; 2018eq; 2018er)
Chondrichthyes	FossilWorks.org (2018es; 2018et; 2018eu; 2018ev; 2018ew; 2018ex)
Actinopterygii	FossilWorks.org (2018ey; 2018ez; 2018fa; 2018fb; 2018fc; 2018fd)
Sarcopterygii	FossilWorks.org (2018fe; 2018ff; 2018fg; 2018fh; 2018fi; 2018fj)
Amphibia	FossilWorks.org (2018fk; 2018fl; 2018fm; 2018fn; 2018fo; 2018fp)
Reptilia	FossilWorks.org (2018fq; 2018fr; 2018fs; 2018ft; 2018fu; 2018fv)
Aves	FossilWorks.org (2018fw; 2018fx; 2018fy; 2018fz; 2018ga; 2018gb)
Mammalia	FossilWorks.org (2018gc; 2018gd; 2018ge; 2018gf; 2018gg; 2018gh)

Appendix 2

Epoch	Age (Mya)	pCO_2 (ppm)	Average pCO_2/Epoch	Used Method	Reference(s)
Paleocene	65,5	750	578	PALEOSOLS ($\delta^{13}C$)	Nordt et al. (2002)
Paleocene	65,5	0	578	PALEOSOLS ($\delta^{13}C$)	Nordt et al. (2003)
Paleocene	65,5	127	578	PALEOSOLS ($\delta^{13}C$)	Nordt et al. (2003)
Paleocene	65,4	271	578	PALEOSOLS ($\delta^{13}C$)	Nordt et al. (2003)
Paleocene	65,2	832	578	PALEOSOLS ($\delta^{13}C$)	Nordt et al. (2003)
Paleocene	65,1	549	578	PALEOSOLS ($\delta^{13}C$)	Nordt et al. (2003)
Paleocene	65,0	0	578	PALEOSOLS ($\delta^{13}C$)	Ekart et al. (1999)
Paleocene	65,0	344	578	STOMATAL INDICES/RATIOS	Beerling et al. (2002)
Paleocene	65,0	339	578	STOMATAL INDICES/RATIOS	Beerling et al. (2002)
Paleocene	64,9	161	578	PALEOSOLS ($\delta^{13}C$)	Nordt et al. (2003)
Paleocene	64,8	533	578	PALEOSOLS ($\delta^{13}C$)	Nordt et al. (2003)
Paleocene	64,8	850	578	PALEOSOLS ($\delta^{13}C$)	Nordt et al. (2002)
Paleocene	64,6	329	578	STOMATAL INDICES/RATIOS	Beerling et al. (2002)
Paleocene	64,6	334	578	PALEOSOLS ($\delta^{13}C$)	Nordt et al. (2003)
Paleocene	64,5	341	578	STOMATAL INDICES/RATIOS	Beerling et al. (2002)
Paleocene	64,4	264	578	PALEOSOLS ($\delta^{13}C$)	Nordt et al. (2003)
Paleocene	64,3	1000	578	PALEOSOLS ($\delta^{13}C$)	Nordt et al. (2002)
Paleocene	64,2	488	578	PALEOSOLS ($\delta^{13}C$)	Nordt et al. (2003)
Paleocene	64,2	534	578	PALEOSOLS ($\delta^{13}C$)	Nordt et al. (2003)
Paleocene	64,0	1519	578	STOMATAL INDICES/RATIOS	Retallack (2001)
Paleocene	61,5	313	578	STOMATAL INDICES/RATIOS	Royer (2003)
Paleocene	59,9	1189	578	MARINE BORON ($\delta^{11}B$)	Demicco et al. (2003)
Paleocene	59,1	451	578	STOMATAL INDICES/RATIOS	Royer et al. (2001)
Paleocene	59,1	409	578	STOMATAL INDICES/RATIOS	Royer et al. (2001)
Paleocene	57,9	353	578	STOMATAL INDICES/RATIOS	Royer et al. (2001)

Paleocene	57,1	703	578	MARINE BORON ($\delta^{11}B$)	Demicco et al. (2003)
Paleocene	57,0	1185	578	PALEOSOLS ($\delta^{13}C$)	Royer et al. (2001)
Paleocene	57,0	363	578	STOMATAL INDICES/RATIOS	Royer et al. (2001)
Paleocene	56,5	307	578	STOMATAL INDICES/RATIOS	Royer et al. (2001)
Paleocene	56,5	314	578	STOMATAL INDICES/RATIOS	Royer et al. (2001)
Paleocene	56,5	312	578	STOMATAL INDICES/RATIOS	Royer et al. (2001)
Paleocene	56,5	2041	578	PALEOSOLS ($\delta^{13}C$)	Royer et al. (2001)
Paleocene	56,4	317	578	STOMATAL INDICES/RATIOS	Royer et al. (2001)
Paleocene	56,3	309	578	STOMATAL INDICES/RATIOS	Royer et al. (2001)
Paleocene	56,2	306	578	STOMATAL INDICES/RATIOS	Royer et al. (2001)
Paleocene	56,0	200	578	PALEOSOLS ($\delta^{13}C$)	Koch et al. (1992)
Paleocene	56,0	200	578	PALEOSOLS ($\delta^{13}C$)	Koch et al. (1992)
Paleocene	56,0	500	578	PALEOSOLS ($\delta^{13}C$)	Sinha & Stott (1994)
Paleocene	56,0	500	578	PALEOSOLS ($\delta^{13}C$)	Sinha & Stott (1994)
Paleocene	56,0	600	578	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Stott (1992)
Paleocene	56,0	299	578	STOMATAL INDICES/RATIOS	Royer et al. (2001)
Paleocene	55,9	390	578	STOMATAL INDICES/RATIOS	Royer et al. (2001)
Paleocene	55,9	300	578	STOMATAL INDICES/RATIOS	Royer et al. (2001)
Paleocene	55,9	1448	578	PALEOSOLS ($\delta^{13}C$)	Royer et al. (2001)
Paleocene	55,9	298	578	STOMATAL INDICES/RATIOS	Royer et al. (2001)
Paleocene	55,9	303	578	STOMATAL INDICES/RATIOS	Royer et al. (2001)
Paleocene	55,8	939	578	MARINE BORON ($\delta^{11}B$)	Demicco et al. (2003)
Paleocene	55,8	826	578	STOMATAL INDICES/RATIOS	Royer et al. (2001)
Paleocene	55,7	373	578	STOMATAL INDICES/RATIOS	Royer et al. (2001)
Paleocene	55,7	1217	578	PALEOSOLS ($\delta^{13}C$)	Royer et al. (2001)
Paleocene	55,5	500	578	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Stott (1992)
Paleocene	55,4	1152	792	PALEOSOLS ($\delta^{13}C$)	Royer et al. (2001)
Paleocene	55,4	360	792	STOMATAL INDICES/RATIOS	Royer et al. (2001)

Eocene	54,5	345	792	STOMATAL INDICES/RATIOS	Royer et al. (2001)
Eocene	54,1	577	792	PALEOSOLS ($\delta^{13}C$)	Royer et al. (2001)
Eocene	54,1	323	792	STOMATAL INDICES/RATIOS	Royer et al. (2001)
Eocene	54,1	370	792	STOMATAL INDICES/RATIOS	Royer (2003)
Eocene	54,0	342	792	STOMATAL INDICES/RATIOS	Royer et al. (2001)
Eocene	53,4	2034	792	PALEOSOLS ($\delta^{13}C$)	Royer et al. (2001)
Eocene	53,2	506	792	MARINE BORON ($\delta^{11}B$)	Demicco et al. (2003)
Eocene	53,0	300	792	PALEOSOLS ($\delta^{13}C$)	Cerling (1992)
Eocene	52,2	1285	792	MARINE BORON ($\delta^{11}B$)	Demicco et al. (2003)
Eocene	52,2	349	792	STOMATAL INDICES/RATIOS	Greenwood et al. (2003)
Eocene	52,0	2700	792	PALEOSOLS ($\delta^{13}C$)	Yapp (2004)
Eocene	51,0	130	792	MARINE BORON ($\delta^{11}B$)	Demicco et al. (2003)
Eocene	50,3	189	792	MARINE BORON ($\delta^{11}B$)	Demicco et al. (2003)
Eocene	50,0	1994	792	STOMATAL INDICES/RATIOS	Retallack (2001)
Eocene	47,0	98	792	MARINE BORON ($\delta^{11}B$)	Demicco et al. (2003)
Eocene	46,1	788	792	MARINE BORON ($\delta^{11}B$)	Demicco et al. (2003)
Eocene	45,7	250	792	MARINE BORON ($\delta^{11}B$)	Demicco et al. (2003)
Eocene	45,0	1950	792	PALEOSOLS ($\delta^{13}C$)	Ekart et al. (1999)
Eocene	45,0	488	792	STOMATAL INDICES/RATIOS	Kürschner et al. (2001)
Eocene	44,3	122	792	MARINE BORON ($\delta^{11}B$)	Demicco et al. (2003)
Eocene	44,0	1176	792	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Eocene	42,9	619	792	STOMATAL INDICES/RATIOS	McElwain (1998)
Eocene	42,9	337	792	STOMATAL INDICES/RATIOS	Greenwood et al. (2003)
Eocene	42,5	71	792	MARINE BORON ($\delta^{11}B$)	Demicco et al. (2003)
Eocene	41,1	1041	792	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Eocene	40,1	253	792	MARINE BORON ($\delta^{11}B$)	Demicco et al. (2003)
Eocene	40,0	670	792	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Freeman & Hayes (1992)
Eocene	39,9	1480	792	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)

Eocene	39,7	996	792	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Eocene	38,0	768	792	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Eocene	37,8	968	792	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Eocene	37,0	1321	792	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Eocene	35,5	786	792	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Eocene	35,2	709	792	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Eocene	35,0	920	792	STOMATAL INDICES/RATIOS	Retallack (2001)
Eocene	34,8	902	792	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Eocene	34,4	901	792	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Eocene	34,1	1093	792	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Oligocene	34,0	521	504	STOMATAL INDICES/RATIOS	Retallack (2001)
Oligocene	33,1	1232	504	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Oligocene	33,0	809	504	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Oligocene	33,0	1326	504	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Oligocene	33,0	832	504	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Oligocene	32,9	864	504	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Oligocene	32,2	1158	504	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Oligocene	30,6	543	504	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Oligocene	30,3	463	504	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Oligocene	30,2	570	504	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Oligocene	30,2	529	504	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Oligocene	30,1	367	504	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Oligocene	30,0	457	504	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Oligocene	29,5	321	504	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Oligocene	28,9	504	504	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Oligocene	28,7	383	504	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Oligocene	28,6	434	504	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Oligocene	27,4	535	504	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)

Oligocene	27,1	582	504	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Oligocene	26,6	367	504	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Oligocene	26,1	386	504	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Oligocene	26,1	419	504	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Oligocene	26,1	420	504	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Oligocene	25,3	359	504	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Oligocene	25,2	351	504	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Oligocene	25,1	602	504	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Oligocene	25,0	294	504	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Oligocene	25,0	1470	504	PALEOSOLS ($\delta^{13}C$)	Ekart et al. (1999)
Oligocene	25,0	343	504	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Oligocene	24,9	331	504	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Oligocene	24,7	749	504	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Oligocene	24,7	466	504	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Oligocene	24,7	392	504	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Oligocene	24,6	248	504	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Oligocene	24,5	222	504	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Oligocene	24,4	246	504	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Oligocene	24,2	256	504	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Oligocene	23,9	271	504	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Oligocene	23,9	242	504	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Oligocene	23,9	287	504	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Oligocene	23,8	257	504	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Oligocene	23,5	297	504	MARINE BORON ($\delta^{11}B$)	Demicco et al. (2003)
Oligocene	23,5	243	504	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Oligocene	23,3	211	504	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	23,0	210	262	MARINE BORON ($\delta^{11}B$)	Demicco et al. (2003)
Miocene	22,2	250	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)

Miocene	21,7	158	262	MARINE BORON (δ^{11}B)	Demicco et al. (2003)
Miocene	21,5	305	262	PHYTOPLANKTON/(FORAMS) (δ^{13}C)	Pagani et al. (2005; 1999a; 1999b)
Miocene	21,1	261	262	PHYTOPLANKTON/(FORAMS) (δ^{13}C)	Pagani et al. (2005; 1999a; 1999b)
Miocene	21,0	780	262	PALEOSOLS (δ^{13}C)	Ekart et al. (1999)
Miocene	20,9	240	262	PHYTOPLANKTON/(FORAMS) (δ^{13}C)	Pagani et al. (2005; 1999a; 1999b)
Miocene	20,8	278	262	PHYTOPLANKTON/(FORAMS) (δ^{13}C)	Pagani et al. (2005; 1999a; 1999b)
Miocene	20,8	202	262	PHYTOPLANKTON/(FORAMS) (δ^{13}C)	Pagani et al. (2005; 1999a; 1999b)
Miocene	20,8	205	262	PHYTOPLANKTON/(FORAMS) (δ^{13}C)	Pagani et al. (2005; 1999a; 1999b)
Miocene	20,8	301	262	PHYTOPLANKTON/(FORAMS) (δ^{13}C)	Pagani et al. (2005; 1999a; 1999b)
Miocene	20,5	208	262	PHYTOPLANKTON/(FORAMS) (δ^{13}C)	Pagani et al. (2005; 1999a; 1999b)
Miocene	20,5	272	262	PHYTOPLANKTON/(FORAMS) (δ^{13}C)	Pagani et al. (2005; 1999a; 1999b)
Miocene	20,4	308	262	PHYTOPLANKTON/(FORAMS) (δ^{13}C)	Pagani et al. (2005; 1999a; 1999b)
Miocene	20,3	343	262	PHYTOPLANKTON/(FORAMS) (δ^{13}C)	Pagani et al. (2005; 1999a; 1999b)
Miocene	20,2	208	262	PHYTOPLANKTON/(FORAMS) (δ^{13}C)	Pagani et al. (2005; 1999a; 1999b)
Miocene	20,0	460	262	PHYTOPLANKTON/(FORAMS) (δ^{13}C)	Freeman & Hayes (1992)
Miocene	20,0	248	262	PHYTOPLANKTON/(FORAMS) (δ^{13}C)	Pagani et al. (2005; 1999a; 1999b)
Miocene	20,0	294	262	PHYTOPLANKTON/(FORAMS) (δ^{13}C)	Pagani et al. (2005; 1999a; 1999b)
Miocene	19,9	157	262	MARINE BORON (δ^{11}B)	Demicco et al. (2003)
Miocene	19,7	250	262	PHYTOPLANKTON/(FORAMS) (δ^{13}C)	Pagani et al. (2005; 1999a; 1999b)
Miocene	19,5	206	262	PHYTOPLANKTON/(FORAMS) (δ^{13}C)	Pagani et al. (2005; 1999a; 1999b)
Miocene	19,4	209	262	PHYTOPLANKTON/(FORAMS) (δ^{13}C)	Pagani et al. (2005; 1999a; 1999b)
Miocene	19,2	224	262	PHYTOPLANKTON/(FORAMS) (δ^{13}C)	Pagani et al. (2005; 1999a; 1999b)
Miocene	19,2	218	262	PHYTOPLANKTON/(FORAMS) (δ^{13}C)	Pagani et al. (2005; 1999a; 1999b)
Miocene	19,2	230	262	PHYTOPLANKTON/(FORAMS) (δ^{13}C)	Pagani et al. (2005; 1999a; 1999b)
Miocene	19,1	230	262	PHYTOPLANKTON/(FORAMS) (δ^{13}C)	Pagani et al. (2005; 1999a; 1999b)
Miocene	18,7	219	262	PHYTOPLANKTON/(FORAMS) (δ^{13}C)	Pagani et al. (2005; 1999a; 1999b)
Miocene	18,6	216	262	PHYTOPLANKTON/(FORAMS) (δ^{13}C)	Pagani et al. (2005; 1999a; 1999b)
Miocene	18,6	232	262	PHYTOPLANKTON/(FORAMS) (δ^{13}C)	Pagani et al. (2005; 1999a; 1999b)

Miocene	18,5	215	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	18,4	216	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	18,4	160	262	MARINE BORON ($\delta^{11}B$)	Demicco et al. (2003)
Miocene	18,3	215	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	18,3	252	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	18,1	228	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	17,9	215	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	17,9	211	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	17,8	197	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	17,8	214	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	17,8	227	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	17,8	215	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	17,7	212	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	17,7	213	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	17,6	207	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	17,6	222	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	17,6	211	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	17,5	231	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	17,5	223	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	17,4	210	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	17,4	216	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	17,3	200	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	17,3	202	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	17,3	232	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	16,8	227	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	16,7	179	262	MARINE BORON ($\delta^{11}B$)	Demicco et al. (2003)
Miocene	16,6	220	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	16,5	396	262	STOMATAL INDICES/RATIOS	Royer et al. (2001)

Miocene	16,4	201	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	16,3	238	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	16,3	179	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	16,2	216	262	MARINE BORON ($\delta^{11}B$)	Demicco et al. (2003)
Miocene	16,2	176	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	16,1	213	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	15,5	205	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	15,4	202	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	15,3	199	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	15,3	316	262	STOMATAL INDICES/RATIOS	Royer et al. (2001)
Miocene	15,3	316	262	STOMATAL INDICES/RATIOS	Royer et al. (2001)
Miocene	15,2	187	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	15,2	310	262	STOMATAL INDICES/RATIOS	Royer et al. (2001)
Miocene	15,1	215	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	15,1	220	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	15,0	229	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	15,0	126	262	MARINE BORON ($\delta^{11}B$)	Demicco et al. (2003)
Miocene	14,9	236	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	14,7	101	262	MARINE BORON ($\delta^{11}B$)	Demicco et al. (2003)
Miocene	14,5	205	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	14,2	220	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	14,1	231	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	14,0	500	262	PALEOSOLS ($\delta^{13}C$)	Cerling (1992)
Miocene	14,0	0	262	PALEOSOLS ($\delta^{13}C$)	Ekart et al. (1999)
Miocene	13,7	213	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	13,6	189	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	13,5	203	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	13,5	223	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)

Miocene	13,4	223	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	13,4	220	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	13,3	229	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	13,3	230	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	13,2	225	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	13,1	205	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	13,1	170	262	MARINE BORON ($\delta^{11}B$)	Demicco et al. (2003)
Miocene	13,0	740	262	PALEOSOLS ($\delta^{13}C$)	Ekart et al. (1999)
Miocene	13,0	440	262	PALEOSOLS ($\delta^{13}C$)	Ekart et al. (1999)
Miocene	13,0	420	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Freeman & Hayes (1992)
Miocene	12,9	228	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	12,9	211	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	12,8	224	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	12,7	203	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	12,7	210	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	12,5	218	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	12,3	213	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	12,2	208	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	12,2	202	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	12,1	213	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	11,9	245	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	11,8	208	262	MARINE BORON ($\delta^{11}B$)	Demicco et al. (2003)
Miocene	11,6	225	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	11,5	204	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	11,4	211	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	11,4	182	262	MARINE BORON ($\delta^{11}B$)	Demicco et al. (2003)
Miocene	11,3	232	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	11,1	220	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)

Miocene	11,0	510	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Freeman & Hayes (1992)
Miocene	10,9	238	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	10,9	228	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	10,7	246	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	10,6	223	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	10,5	370	262	STOMATAL INDICES/RATIOS	Van der Burgh et al. (1993) & Kürschner (1996)
Miocene	10,5	251	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	10,4	193	262	MARINE BORON ($\delta^{11}B$)	Demicco et al. (2003)
Miocene	10,3	243	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	10,2	244	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	10,2	255	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	10,1	245	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	10,0	1120	262	PALEOSOLS ($\delta^{13}C$)	Ekart et al. (1999)
Miocene	10,0	1170	262	PALEOSOLS ($\delta^{13}C$)	Ekart et al. (1999)
Miocene	9,9	235	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	9,8	247	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	9,6	205	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	9,6	234	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	9,6	263	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	9,6	258	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	9,1	268	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	9,1	227	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	9,0	179	262	MARINE BORON ($\delta^{11}B$)	Demicco et al. (2003)
Miocene	9,0	510	262	PALEOSOLS ($\delta^{13}C$)	Ekart et al. (1999)
Miocene	8,7	247	262	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Pagani et al. (2005; 1999a; 1999b)
Miocene	8,5	350	262	STOMATAL INDICES/RATIOS	Van der Burgh et al. (1993) & Kürschner (1996)

Miocene	8,3	237	262	PHYTOPLANKTON/(FORAMS) (δ^{13}C)	Pagani et al. (2005; 1999a; 1999b)
Miocene	8,0	500	262	PALEOSOLS (δ^{13}C)	Cerling (1992)
Miocene	8,0	340	262	PHYTOPLANKTON/(FORAMS) (δ^{13}C)	Freeman & Hayes (1992)
Miocene	7,6	230	262	PHYTOPLANKTON/(FORAMS) (δ^{13}C)	Pagani et al. (2005; 1999a; 1999b)
Miocene	7,3	264	262	PHYTOPLANKTON/(FORAMS) (δ^{13}C)	Pagani et al. (2005; 1999a; 1999b)
Miocene	7,2	270	262	STOMATAL INDICES/RATIOS	Van der Burgh et al. (1993) & Kürschner (1996)
Miocene	7,2	242	262	PHYTOPLANKTON/(FORAMS) (δ^{13}C)	Pagani et al. (2005; 1999a; 1999b)
Miocene	7,0	370	262	PALEOSOLS (δ^{13}C)	Ekart et al. (1999)
Miocene	6,8	278	262	PHYTOPLANKTON/(FORAMS) (δ^{13}C)	Pagani et al. (2005; 1999a; 1999b)
Miocene	6,4	252	262	PHYTOPLANKTON/(FORAMS) (δ^{13}C)	Pagani et al. (2005; 1999a; 1999b)
Miocene	6,2	268	262	MARINE BORON (δ^{11}B)	Demicco et al. (2003)
Miocene	6,1	249	262	PHYTOPLANKTON/(FORAMS) (δ^{13}C)	Pagani et al. (2005; 1999a; 1999b)
Miocene	6,0	730	262	PALEOSOLS (δ^{13}C)	Ekart et al. (1999)
Miocene	6,0	234	262	MARINE BORON (δ^{11}B)	Demicco et al. (2003)
Miocene	5,8	239	262	PHYTOPLANKTON/(FORAMS) (δ^{13}C)	Pagani et al. (2005; 1999a; 1999b)
Miocene	5,4	261	262	PHYTOPLANKTON/(FORAMS) (δ^{13}C)	Pagani et al. (2005; 1999a; 1999b)
Pliocene	5,1	358	405	STOMATAL INDICES/RATIOS	Van der Burgh et al. (1993) & Kürschner (1996)
Pliocene	5,0	350	405	PALEOSOLS (δ^{13}C)	Yapp & Poths (1996)
Pliocene	5,0	810	405	PALEOSOLS (δ^{13}C)	Ekart et al. (1999)
Pliocene	4,6	270	405	STOMATAL INDICES/RATIOS	Van der Burgh et al. (1993) & Kürschner (1996)
Pliocene	4,0	300	405	PALEOSOLS (δ^{13}C)	Cerling (1992)
Pliocene	4,0	363	405	STOMATAL INDICES/RATIOS	Van der Burgh et al. (1993) & Kürschner (1996)
Pliocene	3,9	251	405	MARINE BORON (δ^{11}B)	Demicco et al. (2003)
Pliocene	3,4	358	405	STOMATAL INDICES/RATIOS	Van der Burgh et al. (1993) & Kürschner (1996)

Pliocene	3,3	220	405	MARINE BORON ($\delta^{11}B$)	Demicco et al. (2003)
Pliocene	3,0	1170	405	PALEOSOLS ($\delta^{13}C$)	Ekart et al. (1999)
Pliocene	3,0	184	405	MARINE BORON ($\delta^{11}B$)	Demicco et al. (2003)
Pliocene	2,7	276	405	STOMATAL INDICES/RATIOS	Van der Burgh et al. (1993) & Kürschner (1996)
Pliocene	2,0	358	405	STOMATAL INDICES/RATIOS	Van der Burgh et al. (1993) & Kürschner (1996)
Pleistocene	1,5	271	326	MARINE BORON ($\delta^{11}B$)	Demicco et al. (2003)
Pleistocene	1,0	430	326	PHYTOPLANKTON/(FORAMS) ($\delta^{13}C$)	Freeman & Hayes (1992)
Pleistocene	1,0	286	326	MARINE BORON ($\delta^{11}B$)	Demicco et al. (2003)
Pleistocene	0,1	317	326	MARINE BORON ($\delta^{11}B$)	Demicco et al. (2003)

Appendix 3a

Epoch	Age (Mya)	Deep Ocean Temp. (T_{DO}; °C)	Sea Surface Temp. (T_S; °C)	Sea Level (SL; m)
Paleocene	65,5	8,14	23,29	65
Paleocene	65,5	8,14	23,29	65
Paleocene	65,5	8,14	23,29	65
Paleocene	65,4	8,9	24,05	65
Paleocene	65,2	9,3225	24,4725	65
Paleocene	65,1	8,335	23,485	65
Paleocene	65,0	9,46	24,61	65
Paleocene	65,0	9,46	24,61	65
Paleocene	65,0	9,46	24,61	65
Paleocene	64,9	9,54	24,69	65
Paleocene	64,8	10,36	25,51	65
Paleocene	64,8	10,36	25,51	65
Paleocene	64,6	9,82	24,97	65
Paleocene	64,6	9,82	24,97	65
Paleocene	64,5	9,26	24,41	65
Paleocene	64,4	9,02	24,17	65
Paleocene	64,3	9,52	24,67	65
Paleocene	64,2	9,95	25,1	65
Paleocene	64,2	9,95	25,1	65
Paleocene	64,0	9,35	24,5	65
Paleocene	61,5	9,425	24,575	65
Paleocene	59,9	9,08	24,23	65
Paleocene	59,1	9,326666667	24,47666667	65
Paleocene	59,1	9,326666667	24,47666667	65
Paleocene	57,9	8,923333333	24,07333333	65
Paleocene	57,1	8,975	24,125	65
Paleocene	57,0	8,830333333	23,95333333	65

Paleocene	57,0	8,830333333	23,95333333	65
Paleocene	56,5	9,89	25,04	65
Paleocene	56,5	9,89	25,04	65
Paleocene	56,5	9,89	25,04	65
Paleocene	56,5	9,89	25,04	65
Paleocene	56,4	10,028	25,178	65
Paleocene	56,3	10,19	25,34	65
Paleocene	56,2	9,816666667	24,96666667	65
Paleocene	56,0	10	25,15	65
Paleocene	56,0	10	25,15	65
Paleocene	56,0	10	25,15	65
Paleocene	56,0	10	25,15	65
Paleocene	56,0	10	25,15	65
Paleocene	56,0	10	25,15	65
Paleocene	55,9	10,415	25,565	65
Paleocene	55,9	10,415	25,565	65
Paleocene	55,9	10,415	25,565	65
Paleocene	55,9	10,415	25,565	65
Paleocene	55,9	10,415	25,565	65
Paleocene	55,8	10,29666667	25,44666667	65
Paleocene	55,8	10,29666667	25,44666667	65
Paleocene	55,7	10,52333333	25,67333333	65
Paleocene	55,7	10,52333333	25,67333333	65
Paleocene	55,5	9,7976	24,9475	65
Paleocene	55,4	9,876666667	25,02666667	65
Paleocene	55,4	9,876666667	25,02666667	65
Eocene	54,5	11,45333333	26,60333333	65
Eocene	54,1	11,0025	26,1525	65
Eocene	54,1	11,0025	26,1525	65
Eocene	54,1	11,0025	26,1525	65
Eocene	54,0	10,462	25,612	65
Eocene	53,4	11,35	26,5	65

Eocene	53,2	11,77333333	26,92333333	65
Eocene	53,0	11,7825	26,9325	65
Eocene	52,2	12,25	27,4	65
Eocene	52,2	12,25	27,4	65
Eocene	52,0	12,135	27,285	65
Eocene	51,0	12,26	27,41	65
Eocene	50,3	12,31	27,46	65
Eocene	50,0	11,83	26,98	65
Eocene	47,0	10,23	25,38	65
Eocene	46,1	9,515	24,665	65
Eocene	45,7	8,87	24,02	65
Eocene	45,0	7,93	23,08	65
Eocene	45,0	7,93	23,08	65
Eocene	44,3	7,8175	22,9675	65
Eocene	44,0	7,86	23,01	65
Eocene	42,9	8,016666667	23,16666667	65
Eocene	42,9	8,016666667	23,16666667	65
Eocene	42,5	7,763333333	22,91333333	65
Eocene	41,1	7,399	22,549	65
Eocene	40,1	6,986666667	22,13666667	65
Eocene	40,0	7,495	22,645	65
Eocene	39,9	7,2675	22,4175	65
Eocene	39,7	7,43	22,58	65
Eocene	38,0	6,004	21,154	65
Eocene	37,8	5,38	20,53	65
Eocene	37,0	5,46	20,61	65
Eocene	35,5	5,115	20,265	65
Eocene	35,2	5,14	20,29	65
Eocene	35,0	5,478	20,628	65,36
Eocene	34,8	5,064375	20,214375	60,5625
Eocene	34,4	4,970769231	20,32346154	59,15
Eocene	34,1	5,10041667	20,25041667	60,275

Oligocene	34,0	5,107173913	18,94673913	66,73913043
Oligocene	33,1	2,92265625	18,07265625	28,8421875
Oligocene	33,0	3,4124	18,2594	37,092
Oligocene	33,0	3,4124	18,2594	37,092
Oligocene	33,0	3,4124	18,2594	37,092
Oligocene	32,9	3,410357143	19,85696429	36,1625
Oligocene	32,2	3,66122449	18,81122449	39,20857143
Oligocene	30,6	3,17097561	17,50853659	33,8
Oligocene	30,3	3,706	19,78892308	38,47076923
Oligocene	30,2	3,579655172	18,72965517	38,68965517
Oligocene	30,2	3,579655172	18,72965517	38,68965517
Oligocene	30,1	3,617857143	18,76785714	39,01928571
Oligocene	30,0	3,856097561	19,00609756	42,85121951
Oligocene	29,5	3,81826087	18,96826087	42,2826087
Oligocene	28,9	3,726388889	18,8675	40,89722222
Oligocene	28,7	3,326551724	18,47655172	34,88965517
Oligocene	28,6	3,793333333	18,95952381	41,9
Oligocene	27,4	3,068275862	18,21827586	31,02413793
Oligocene	27,1	3,36	18,51	35,38043478
Oligocene	26,6	4,1304	19,2804	46,95466667
Oligocene	26,1	4,392361111	19,54236111	50,84722222
Oligocene	26,1	4,392361111	19,54236111	50,84722222
Oligocene	26,1	4,392361111	19,54236111	50,84722222
Oligocene	25,3	4,679444444	19,82944444	55,12407407
Oligocene	25,2	4,574571429	19,72457143	53,57142857
Oligocene	25,1	4,624107143	19,77410714	54,32142857
Oligocene	25,0	4,643191489	19,79319149	54,64042553
Oligocene	25,0	4,643191489	19,79319149	54,64042553
Oligocene	25,0	4,643191489	19,79319149	54,64042553
Oligocene	24,9	4,899622642	20,04962264	58,08113208
Oligocene	24,7	4,741153846	19,89115385	56,05192308
Oligocene	24,7	4,741153846	19,89115385	56,05192308

Oligocene	24,7	4,741153846	19,89115385	56,05192308
Oligocene	24,6	4,899591837	20,04959184	57,87959184
Oligocene	24,5	4,698142857	19,84814286	55,33285714
Oligocene	24,4	4,504166667	19,65416667	52,53
Oligocene	24,2	4,997346939	20,14734694	58,93469388
Oligocene	23,9	4,137386364	19,28738636	47,06477273
Oligocene	23,9	4,137386364	19,28738636	47,06477273
Oligocene	23,9	4,137386364	19,28738636	47,06477273
Oligocene	23,8	4,090595238	19,24059524	46,35238095
Oligocene	23,5	3,944150943	19,09415094	44,15849057
Oligocene	23,5	3,944150943	19,09415094	44,15849057
Oligocene	23,3	4,36375	19,51375	50,459375
Miocene	23,0	3,279710145	18,42971014	34,05507246
Miocene	22,2	3,992222222	19,14222222	44,89444444
Miocene	21,7	4,867560976	20,01682927	57,25365854
Miocene	21,5	4,641875	19,78979167	54,56666667
Miocene	21,1	3,400416667	18,55708333	36,02083333
Miocene	21,0	3,523928571	18,67392857	37,85357143
Miocene	20,9	3,823548387	18,97354839	42,3483871
Miocene	20,8	4,279705882	19,42970588	49,18529412
Miocene	20,8	4,279705882	19,42970588	49,18529412
Miocene	20,8	4,279705882	19,42970588	49,18529412
Miocene	20,8	4,279705882	19,42970588	49,18529412
Miocene	20,5	4,284897959	19,4355102	49,25102041
Miocene	20,5	4,284897959	19,4355102	49,25102041
Miocene	20,4	4,419111111	19,56911111	51,24888889
Miocene	20,3	4,2552	19,4052	48,834
Miocene	20,2	3,733809524	18,88380952	41,00952381
Miocene	20,0	4,2	19,35	47,9862069
Miocene	20,0	4,2	19,35	47,9862069
Miocene	20,0	4,2	19,35	47,9862069
Miocene	19,9	3,970204082	19,12020408	44,54081633

Miocene	19,7	3,445319149	18,59531915	36,67659574
Miocene	19,5	3,564166667	18,71416667	38,4625
Miocene	19,4	3,521016949	18,22254237	31,08644068
Miocene	19,2	3,746909091	18,89690909	41,20545455
Miocene	19,2	3,746909091	18,89690909	41,20545455
Miocene	19,2	3,746909091	18,89690909	41,20545455
Miocene	19,1	3,31	18,46	34,6575
Miocene	18,7	3,781428571	18,93142857	41,71071429
Miocene	18,6	3,396122449	18,54612245	35,94285714
Miocene	18,6	3,396122449	18,54612245	35,94285714
Miocene	18,5	3,81826087	18,96826087	42,28043478
Miocene	18,4	3,71755102	18,86755102	40,77346939
Miocene	18,4	3,71755102	18,86755102	40,77346939
Miocene	18,3	3,620697674	18,77069767	39,31162791
Miocene	18,3	3,620697674	18,77069767	39,31162791
Miocene	18,1	3,946904762	19,09690476	44,18333333
Miocene	17,9	3,787555556	18,93755556	41,81555556
Miocene	17,9	3,787555556	18,93755556	41,81555556
Miocene	17,8	3,653488372	18,80348837	39,8
Miocene	17,8	3,653488372	18,80348837	39,8
Miocene	17,8	3,653488372	18,80348837	39,8
Miocene	17,8	3,653488372	18,80348837	39,8
Miocene	17,7	3,624736842	18,77473684	39,37894737
Miocene	17,7	3,624736842	18,77473684	39,37894737
Miocene	17,6	3,887894737	19,03789474	43,33157895
Miocene	17,6	3,887894737	19,03789474	43,33157895
Miocene	17,6	3,887894737	19,03789474	43,33157895
Miocene	17,5	3,5925	18,7425	38,91
Miocene	17,5	3,5925	18,7425	38,91
Miocene	17,4	3,517142857	18,66714286	37,76428571
Miocene	17,4	3,517142857	18,66714286	37,76428571
Miocene	17,3	3,57875	18,72875	38,68333333

Miocene	17,3	3,57875	18,72875	38,68333333
Miocene	17,3	3,57875	18,72875	38,68333333
Miocene	16,8	4,746315789	19,89631579	55,86315789
Miocene	16,7	4,532352941	19,68235294	53
Miocene	16,6	5,01	20,16	59,16111111
Miocene	16,5	5,053461538	20,20346154	59,73461538
Miocene	16,4	5,00037037	20,15037037	59,30740741
Miocene	16,3	5,222962963	20,37296296	61,78148148
Miocene	16,3	5,222962963	20,37296296	61,78148148
Miocene	16,2	4,298421053	19,44842105	49,47894737
Miocene	16,2	4,298421053	19,44842105	49,47894737
Miocene	16,1	4,311034483	19,46103448	49,65862069
Miocene	15,5	5,15	20,3	61,24545455
Miocene	15,4	5,433333333	20,58333333	64,26666667
Miocene	15,3	5,414545455	20,56454545	63,63636364
Miocene	15,3	5,414545455	20,56454545	63,63636364
Miocene	15,3	5,414545455	20,56454545	63,63636364
Miocene	15,2	4,727272727	19,87727273	55,94545455
Miocene	15,2	4,727272727	19,87727273	55,94545455
Miocene	15,1	5,226666667	20,37666667	62,21111111
Miocene	15,1	5,226666667	20,37666667	62,21111111
Miocene	15,0	5,281481481	20,43148148	62,66296296
Miocene	15,0	5,281481481	20,43148148	62,66296296
Miocene	14,9	5,139642857	20,28964286	61,15714286
Miocene	14,7	5,275625	20,425625	62,68125
Miocene	14,5	4,6135	19,7635	54,2025
Miocene	14,2	4,627142857	19,77714286	54,25
Miocene	14,1	4,372307692	19,52230769	50,6
Miocene	14,0	4,86	20,01	57,68125
Miocene	14,0	4,86	20,01	57,68125
Miocene	13,7	3,690454545	18,84045455	40,34545455
Miocene	13,6	3,626285714	18,77628571	39,40285714

Miocene	13,5	3,645471698	18,7954717	39,67735849
Miocene	13,5	3,645471698	18,7954717	39,67735849
Miocene	13,4	3,728039216	18,87411765	40,86666667
Miocene	13,4	3,728039216	18,87411765	40,86666667
Miocene	13,3	3,924222222	19,07422222	43,86
Miocene	13,3	3,924222222	19,07422222	43,86
Miocene	13,2	3,708196721	18,85819672	40,62295082
Miocene	13,1	3,526923077	18,67692308	37,91282051
Miocene	13,1	3,526923077	18,67692308	37,91282051
Miocene	13,0	3,390714286	18,54071429	35,87142857
Miocene	13,0	3,390714286	18,54071429	35,87142857
Miocene	13,0	3,390714286	18,54071429	35,87142857
Miocene	12,9	3,395135135	18,54513514	35,92162162
Miocene	12,9	3,395135135	18,54513514	35,92162162
Miocene	12,8	3,037959184	18,18795918	30,56734694
Miocene	12,7	3,126507937	18,27650794	31,89365079
Miocene	12,7	3,126507937	18,27650794	31,89365079
Miocene	12,5	3,089	18,239	31,33666667
Miocene	12,3	3,056923077	18,20692308	30,85384615
Miocene	12,2	3,253333333	18,40333333	33,8
Miocene	12,2	3,253333333	18,40333333	33,8
Miocene	12,1	3,03	18,18	30,44736842
Miocene	11,9	3,084545455	18,23454545	31,25454545
Miocene	11,8	2,9965	18,1465	29,945
Miocene	11,6	2,961111111	18,11111111	29,43888889
Miocene	11,5	2,433809524	17,58380952	21,5047619
Miocene	11,4	2,691818182	17,84181818	25,37272727
Miocene	11,4	2,691818182	17,84181818	25,37272727
Miocene	11,3	2,99	18,14	29,87272727
Miocene	11,1	3,0185	18,1685	30,27
Miocene	11,0	2,924166667	18,07416667	28,86666667
Miocene	10,9	2,918181818	18,06818182	28,79090909

Miocene	10,9	2,918181818	18,06818182	28,79090909
Miocene	10,7	2,745	17,895	26,17
Miocene	10,6	2,552	17,702	23,28
Miocene	10,5	2,77875	17,92875	26,675
Miocene	10,5	2,77875	17,92875	26,675
Miocene	10,4	2,839	17,989	27,59
Miocene	10,3	2,63375	17,78375	24,4875
Miocene	10,2	2,371428571	17,52142857	20,55714286
Miocene	10,2	2,371428571	17,52142857	20,55714286
Miocene	10,1	2,515454545	17,66545455	22,71818182
Miocene	10,0	2,594	17,744	23,91
Miocene	10,0	2,594	17,744	23,91
Miocene	9,9	2,5575	17,7075	23,3375
Miocene	9,8	2,617142857	17,76714286	24,27142857
Miocene	9,6	2,495185185	17,64518519	22,42962963
Miocene	9,6	2,495185185	17,64518519	22,42962963
Miocene	9,6	2,495185185	17,64518519	22,42962963
Miocene	9,6	2,495185185	17,64518519	22,42962963
Miocene	9,1	2,264117647	17,41411765	18,95882353
Miocene	9,1	2,264117647	17,41411765	18,95882353
Miocene	9,0	3,343529412	17,46117647	19,65882353
Miocene	9,0	3,343529412	17,46117647	19,65882353
Miocene	8,7	2,222	17,372	18,32
Miocene	8,5	2,067142857	17,21714286	15,98571429
Miocene	8,3	2,047142857	17,19714286	15,71904762
Miocene	8,0	2,008888889	17,15888889	15,15555556
Miocene	8,0	2,008888889	17,15888889	15,15555556
Miocene	7,6	2,41	17,56	21,13333333
Miocene	7,3	2,758823529	17,90882353	26,38235294
Miocene	7,2	2,117727273	17,26772727	16,76818182
Miocene	7,2	2,117727273	17,26772727	16,76818182
Miocene	7,0	2,515384615	17,66538462	22,72307692

Miocene	6,8	2,301818182	17,45181818	19,51818182
Miocene	6,4	2,711724138	17,29068966	17,10344828
Miocene	6,2	2,3108	17,4608	19,672
Miocene	6,1	1,8476	16,9976	12,708
Miocene	6,0	1,644883721	16,82139535	9,668604651
Miocene	6,0	1,644883721	16,82139535	9,668604651
Miocene	5,8	1,530126582	16,68012658	7,573670886
Miocene	5,4	2,129857143	17,27985714	16,94571429
Pliocene	5,1	1,977101449	17,09376812	14,66086957
Pliocene	5,0	1,954666667	17,03826667	14,32533333
Pliocene	5,0	1,954666667	17,03826667	14,32533333
Pliocene	4,6	1,401057692	15,65240385	6,010576923
Pliocene	4,0	1,253411765	15,28423529	2,957647059
Pliocene	4,0	1,253411765	15,28423529	2,957647059
Pliocene	3,9	1,688690476	16,37285714	10,34285714
Pliocene	3,4	1,138977273	14,85669318	0,282954545
Pliocene	3,3	1,057118644	14,7929661	-3,23559322
Pliocene	3,0	1,052764228	14,78154472	-1,690243902
Pliocene	3,0	1,052764228	14,78154472	-1,690243902
Pliocene	2,7	0,537295082	13,49229508	-23,69836066
Pliocene	2,0	0,422932331	13,2081203	-28,37503759
Pleistocene	1,5	0,001486486	12,25310811	-49,50405405
Pleistocene	1,0	0,050775	12,33975	-47,4175
Pleistocene	1,0	0,050775	12,33975	-47,4175
Pleistocene	0,1	-0,162745098	11,93029412	-58,99117647

Appendix 3b

Epoch	Age (Mya)	Average T_{DO}/Epoch	Average T_S/Epoch	Average SL/Epoch	References
Paleocene	65,5	9,658215723	24,80719497	65	Hansen et al. (2013); Zachos et al. (2008)
Paleocene	65,5	9,658215723	24,80719497	65	Hansen et al. (2013); Zachos et al. (2008)
Paleocene	65,5	9,658215723	24,80719497	65	Hansen et al. (2013); Zachos et al. (2008)
Paleocene	65,4	9,658215723	24,80719497	65	Hansen et al. (2013); Zachos et al. (2008)
Paleocene	65,2	9,658215723	24,80719497	65	Hansen et al. (2013); Zachos et al. (2008)
Paleocene	65,1	9,658215723	24,80719497	65	Hansen et al. (2013); Zachos et al. (2008)
Paleocene	65,0	9,658215723	24,80719497	65	Hansen et al. (2013); Zachos et al. (2008)
Paleocene	65,0	9,658215723	24,80719497	65	Hansen et al. (2013); Zachos et al. (2008)
Paleocene	65,0	9,658215723	24,80719497	65	Hansen et al. (2013); Zachos et al. (2008)
Paleocene	64,9	9,658215723	24,80719497	65	Hansen et al. (2013); Zachos et al. (2008)
Paleocene	64,8	9,658215723	24,80719497	65	Hansen et al. (2013); Zachos et al. (2008)
Paleocene	64,8	9,658215723	24,80719497	65	Hansen et al. (2013); Zachos et al. (2008)
Paleocene	64,6	9,658215723	24,80719497	65	Hansen et al. (2013); Zachos et al. (2008)
Paleocene	64,6	9,658215723	24,80719497	65	Hansen et al. (2013); Zachos et al. (2008)
Paleocene	64,5	9,658215723	24,80719497	65	Hansen et al. (2013); Zachos et al. (2008)
Paleocene	64,4	9,658215723	24,80719497	65	Hansen et al. (2013); Zachos et al. (2008)
Paleocene	64,3	9,658215723	24,80719497	65	Hansen et al. (2013); Zachos et al. (2008)
Paleocene	64,2	9,658215723	24,80719497	65	Hansen et al. (2013); Zachos et al. (2008)
Paleocene	64,2	9,658215723	24,80719497	65	Hansen et al. (2013); Zachos et al. (2008)

Paleocene	64,0	9,658215723	24,80719497	65	Hansen et al. (2013); Zachos et al. (2008)
Paleocene	61,5	9,658215723	24,80719497	65	Hansen et al. (2013); Zachos et al. (2008)
Paleocene	59,9	9,658215723	24,80719497	65	Hansen et al. (2013); Zachos et al. (2008)
Paleocene	59,1	9,658215723	24,80719497	65	Hansen et al. (2013); Zachos et al. (2008)
Paleocene	59,1	9,658215723	24,80719497	65	Hansen et al. (2013); Zachos et al. (2008)
Paleocene	57,9	9,658215723	24,80719497	65	Hansen et al. (2013); Zachos et al. (2008)
Paleocene	57,1	9,658215723	24,80719497	65	Hansen et al. (2013); Zachos et al. (2008)
Paleocene	57,0	9,658215723	24,80719497	65	Hansen et al. (2013); Zachos et al. (2008)
Paleocene	57,0	9,658215723	24,80719497	65	Hansen et al. (2013); Zachos et al. (2008)
Paleocene	56,5	9,658215723	24,80719497	65	Hansen et al. (2013); Zachos et al. (2008)
Paleocene	56,5	9,658215723	24,80719497	65	Hansen et al. (2013); Zachos et al. (2008)
Paleocene	56,5	9,658215723	24,80719497	65	Hansen et al. (2013); Zachos et al. (2008)
Paleocene	56,5	9,658215723	24,80719497	65	Hansen et al. (2013); Zachos et al. (2008)
Paleocene	56,4	9,658215723	24,80719497	65	Hansen et al. (2013); Zachos et al. (2008)
Paleocene	56,3	9,658215723	24,80719497	65	Hansen et al. (2013); Zachos et al. (2008)
Paleocene	56,2	9,658215723	24,80719497	65	Hansen et al. (2013); Zachos et al. (2008)
Paleocene	56,0	9,658215723	24,80719497	65	Hansen et al. (2013); Zachos et al. (2008)
Paleocene	56,0	9,658215723	24,80719497	65	Hansen et al. (2013); Zachos et al. (2008)
Paleocene	56,0	9,658215723	24,80719497	65	Hansen et al. (2013); Zachos et al. (2008)
Paleocene	56,0	9,658215723	24,80719497	65	Hansen et al. (2013); Zachos et al. (2008)
Paleocene	56,0	9,658215723	24,80719497	65	Hansen et al. (2013); Zachos et al. (2008)
Paleocene	56,0	9,658215723	24,80719497	65	Hansen et al. (2013); Zachos et al. (2008)
Paleocene	55,9	9,658215723	24,80719497	65	Hansen et al. (2013); Zachos et al. (2008)
Paleocene	55,9	9,658215723	24,80719497	65	Hansen et al. (2013); Zachos et al. (2008)
Paleocene	55,9	9,658215723	24,80719497	65	Hansen et al. (2013); Zachos et al. (2008)
Paleocene	55,9	9,658215723	24,80719497	65	Hansen et al. (2013); Zachos et al. (2008)
Paleocene	55,9	9,658215723	24,80719497	65	Hansen et al. (2013); Zachos et al. (2008)
Paleocene	55,8	9,658215723	24,80719497	65	Hansen et al. (2013); Zachos et al. (2008)

Paleocene	55,8	9,658215723	24,80719497	65	Hansen et al. (2013); Zachos et al. (2008)
Paleocene	55,7	9,658215723	24,80719497	65	Hansen et al. (2013); Zachos et al. (2008)
Paleocene	55,7	9,658215723	24,80719497	65	Hansen et al. (2013); Zachos et al. (2008)
Paleocene	55,5	9,658215723	24,80719497	65	Hansen et al. (2013); Zachos et al. (2008)
Paleocene	55,4	9,658215723	24,80719497	65	Hansen et al. (2013); Zachos et al. (2008)
Paleocene	55,4	9,658215723	24,80719497	65	Hansen et al. (2013); Zachos et al. (2008)
Eocene	54,5	8,713251603	23,86858561	64,61440789	Hansen et al. (2013); Zachos et al. (2008)
Eocene	54,1	8,713251603	23,86858561	64,61440789	Hansen et al. (2013); Zachos et al. (2008)
Eocene	54,1	8,713251603	23,86858561	64,61440789	Hansen et al. (2013); Zachos et al. (2008)
Eocene	54,1	8,713251603	23,86858561	64,61440789	Hansen et al. (2013); Zachos et al. (2008)
Eocene	54,0	8,713251603	23,86858561	64,61440789	Hansen et al. (2013); Zachos et al. (2008)
Eocene	53,4	8,713251603	23,86858561	64,61440789	Hansen et al. (2013); Zachos et al. (2008)
Eocene	53,2	8,713251603	23,86858561	64,61440789	Hansen et al. (2013); Zachos et al. (2008)
Eocene	53,0	8,713251603	23,86858561	64,61440789	Hansen et al. (2013); Zachos et al. (2008)
Eocene	52,2	8,713251603	23,86858561	64,61440789	Hansen et al. (2013); Zachos et al. (2008)
Eocene	52,2	8,713251603	23,86858561	64,61440789	Hansen et al. (2013); Zachos et al. (2008)
Eocene	52,0	8,713251603	23,86858561	64,61440789	Hansen et al. (2013); Zachos et al. (2008)
Eocene	51,0	8,713251603	23,86858561	64,61440789	Hansen et al. (2013); Zachos et al. (2008)
Eocene	50,3	8,713251603	23,86858561	64,61440789	Hansen et al. (2013); Zachos et al. (2008)
Eocene	50,0	8,713251603	23,86858561	64,61440789	Hansen et al. (2013); Zachos et al. (2008)
Eocene	47,0	8,713251603	23,86858561	64,61440789	Hansen et al. (2013); Zachos et al. (2008)
Eocene	46,1	8,713251603	23,86858561	64,61440789	Hansen et al. (2013); Zachos et al. (2008)
Eocene	45,7	8,713251603	23,86858561	64,61440789	Hansen et al. (2013); Zachos et al. (2008)
Eocene	45,0	8,713251603	23,86858561	64,61440789	Hansen et al. (2013); Zachos et al. (2008)
Eocene	45,0	8,713251603	23,86858561	64,61440789	Hansen et al. (2013); Zachos et al. (2008)
Eocene	44,3	8,713251603	23,86858561	64,61440789	Hansen et al. (2013); Zachos et al. (2008)
Eocene	44,0	8,713251603	23,86858561	64,61440789	Hansen et al. (2013); Zachos et al. (2008)
Eocene	42,9	8,713251603	23,86858561	64,61440789	Hansen et al. (2013); Zachos et al. (2008)

Eocene	42,9	8,713251603	23,86858561	64,61440789	Hansen et al. (2013); Zachos et al. (2008)
Eocene	42,5	8,713251603	23,86858561	64,61440789	Hansen et al. (2013); Zachos et al. (2008)
Eocene	41,1	8,713251603	23,86858561	64,61440789	Hansen et al. (2013); Zachos et al. (2008)
Eocene	40,1	8,713251603	23,86858561	64,61440789	Hansen et al. (2013); Zachos et al. (2008)
Eocene	40,0	8,713251603	23,86858561	64,61440789	Hansen et al. (2013); Zachos et al. (2008)
Eocene	39,9	8,713251603	23,86858561	64,61440789	Hansen et al. (2013); Zachos et al. (2008)
Eocene	39,7	8,713251603	23,86858561	64,61440789	Hansen et al. (2013); Zachos et al. (2008)
Eocene	38,0	8,713251603	23,86858561	64,61440789	Hansen et al. (2013); Zachos et al. (2008)
Eocene	37,8	8,713251603	23,86858561	64,61440789	Hansen et al. (2013); Zachos et al. (2008)
Eocene	37,0	8,713251603	23,86858561	64,61440789	Hansen et al. (2013); Zachos et al. (2008)
Eocene	35,5	8,713251603	23,86858561	64,61440789	Hansen et al. (2013); Zachos et al. (2008)
Eocene	35,2	8,713251603	23,86858561	64,61440789	Hansen et al. (2013); Zachos et al. (2008)
Eocene	35,0	8,713251603	23,86858561	64,61440789	Hansen et al. (2013); Zachos et al. (2008)
Eocene	34,8	8,713251603	23,86858561	64,61440789	Hansen et al. (2013); Zachos et al. (2008)
Eocene	34,4	8,713251603	23,86858561	64,61440789	Hansen et al. (2013); Zachos et al. (2008)
Eocene	34,1	8,713251603	23,86858561	64,61440789	Hansen et al. (2013); Zachos et al. (2008)
Oligocene	34,0	4,091681424	19,22361229	46,44987894	Hansen et al. (2013); Zachos et al. (2008)
Oligocene	33,1	4,091681424	19,22361229	46,44987894	Hansen et al. (2013); Zachos et al. (2008)
Oligocene	33,0	4,091681424	19,22361229	46,44987894	Hansen et al. (2013); Zachos et al. (2008)
Oligocene	33,0	4,091681424	19,22361229	46,44987894	Hansen et al. (2013); Zachos et al. (2008)
Oligocene	33,0	4,091681424	19,22361229	46,44987894	Hansen et al. (2013); Zachos et al. (2008)
Oligocene	32,9	4,091681424	19,22361229	46,44987894	Hansen et al. (2013); Zachos et al. (2008)
Oligocene	32,2	4,091681424	19,22361229	46,44987894	Hansen et al. (2013); Zachos et al. (2008)
Oligocene	30,6	4,091681424	19,22361229	46,44987894	Hansen et al. (2013); Zachos et al. (2008)
Oligocene	30,3	4,091681424	19,22361229	46,44987894	Hansen et al. (2013); Zachos et al. (2008)
Oligocene	30,2	4,091681424	19,22361229	46,44987894	Hansen et al. (2013); Zachos et al. (2008)
Oligocene	30,2	4,091681424	19,22361229	46,44987894	Hansen et al. (2013); Zachos et al. (2008)
Oligocene	30,1	4,091681424	19,22361229	46,44987894	Hansen et al. (2013); Zachos et al. (2008)

Oligocene	30,0	4,091681424	19,22361229	46,44987894	Hansen et al. (2013); Zachos et al. (2008)
Oligocene	29,5	4,091681424	19,22361229	46,44987894	Hansen et al. (2013); Zachos et al. (2008)
Oligocene	28,9	4,091681424	19,22361229	46,44987894	Hansen et al. (2013); Zachos et al. (2008)
Oligocene	28,7	4,091681424	19,22361229	46,44987894	Hansen et al. (2013); Zachos et al. (2008)
Oligocene	28,6	4,091681424	19,22361229	46,44987894	Hansen et al. (2013); Zachos et al. (2008)
Oligocene	27,4	4,091681424	19,22361229	46,44987894	Hansen et al. (2013); Zachos et al. (2008)
Oligocene	27,1	4,091681424	19,22361229	46,44987894	Hansen et al. (2013); Zachos et al. (2008)
Oligocene	26,6	4,091681424	19,22361229	46,44987894	Hansen et al. (2013); Zachos et al. (2008)
Oligocene	26,1	4,091681424	19,22361229	46,44987894	Hansen et al. (2013); Zachos et al. (2008)
Oligocene	26,1	4,091681424	19,22361229	46,44987894	Hansen et al. (2013); Zachos et al. (2008)
Oligocene	26,1	4,091681424	19,22361229	46,44987894	Hansen et al. (2013); Zachos et al. (2008)
Oligocene	25,3	4,091681424	19,22361229	46,44987894	Hansen et al. (2013); Zachos et al. (2008)
Oligocene	25,2	4,091681424	19,22361229	46,44987894	Hansen et al. (2013); Zachos et al. (2008)
Oligocene	25,1	4,091681424	19,22361229	46,44987894	Hansen et al. (2013); Zachos et al. (2008)
Oligocene	25,0	4,091681424	19,22361229	46,44987894	Hansen et al. (2013); Zachos et al. (2008)
Oligocene	25,0	4,091681424	19,22361229	46,44987894	Hansen et al. (2013); Zachos et al. (2008)
Oligocene	25,0	4,091681424	19,22361229	46,44987894	Hansen et al. (2013); Zachos et al. (2008)
Oligocene	24,9	4,091681424	19,22361229	46,44987894	Hansen et al. (2013); Zachos et al. (2008)
Oligocene	24,7	4,091681424	19,22361229	46,44987894	Hansen et al. (2013); Zachos et al. (2008)
Oligocene	24,7	4,091681424	19,22361229	46,44987894	Hansen et al. (2013); Zachos et al. (2008)
Oligocene	24,7	4,091681424	19,22361229	46,44987894	Hansen et al. (2013); Zachos et al. (2008)
Oligocene	24,6	4,091681424	19,22361229	46,44987894	Hansen et al. (2013); Zachos et al. (2008)
Oligocene	24,5	4,091681424	19,22361229	46,44987894	Hansen et al. (2013); Zachos et al. (2008)
Oligocene	24,4	4,091681424	19,22361229	46,44987894	Hansen et al. (2013); Zachos et al. (2008)
Oligocene	24,2	4,091681424	19,22361229	46,44987894	Hansen et al. (2013); Zachos et al. (2008)
Oligocene	23,9	4,091681424	19,22361229	46,44987894	Hansen et al. (2013); Zachos et al. (2008)
Oligocene	23,9	4,091681424	19,22361229	46,44987894	Hansen et al. (2013); Zachos et al. (2008)
Oligocene	23,9	4,091681424	19,22361229	46,44987894	Hansen et al. (2013); Zachos et al. (2008)

Oligocene	23,8	4,091681424	19,22361229	46,44987894	Hansen et al. (2013); Zachos et al. (2008)
Oligocene	23,5	4,091681424	19,22361229	46,44987894	Hansen et al. (2013); Zachos et al. (2008)
Oligocene	23,5	4,091681424	19,22361229	46,44987894	Hansen et al. (2013); Zachos et al. (2008)
Oligocene	23,3	4,091681424	19,22361229	46,44987894	Hansen et al. (2013); Zachos et al. (2008)
Miocene	23,0	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	22,2	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	21,7	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	21,5	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	21,1	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	21,0	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	20,9	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	20,8	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	20,8	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	20,8	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
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Miocene	19,7	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	19,5	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	19,4	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	19,2	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)

Miocene	19,2	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	19,2	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	19,1	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	18,7	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	18,6	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	18,6	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	18,5	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	18,4	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	18,4	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	18,3	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	18,3	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	18,1	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
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Miocene	17,9	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
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Miocene	17,8	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	17,8	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	17,8	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
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Miocene	17,6	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	17,6	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	17,5	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	17,5	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	17,4	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	17,4	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	17,3	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)

Miocene	17,3	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	17,3	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
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Miocene	16,7	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	16,6	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	16,5	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	16,4	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	16,3	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	16,3	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	16,2	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	16,2	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	16,1	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	15,5	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	15,4	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	15,3	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	15,3	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	15,3	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	15,2	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	15,2	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	15,1	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	15,1	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	15,0	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	15,0	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	14,9	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	14,7	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	14,5	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	14,2	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	14,1	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)

Miocene	14,0	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	14,0	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	13,7	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	13,6	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	13,5	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	13,5	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	13,4	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	13,4	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	13,3	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	13,3	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	13,2	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	13,1	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	13,1	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	13,0	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	13,0	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	13,0	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	12,9	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	12,9	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	12,8	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	12,7	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	12,7	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	12,5	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	12,3	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	12,2	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	12,2	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	12,1	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	11,9	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	11,8	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)

Miocene	11,6	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	11,5	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	11,4	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	11,4	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	11,3	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	11,1	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	11,0	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	10,9	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	10,9	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	10,7	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	10,6	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	10,5	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	10,5	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
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Miocene	10,3	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
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Miocene	10,0	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
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Miocene	9,9	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	9,8	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
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Miocene	9,6	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	9,6	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	9,6	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	9,1	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	9,1	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)

Miocene	9,0	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	9,0	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	8,7	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	8,5	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	8,3	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	8,0	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	8,0	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	7,6	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	7,3	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	7,2	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	7,2	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	7,0	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	6,8	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	6,4	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	6,2	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	6,1	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	6,0	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	6,0	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	5,8	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Miocene	5,4	3,544047327	18,67459887	37,69035928	Hansen et al. (2013); Zachos et al. (2008)
Pliocene	5,1	1,28806602	15,35978439	0,55182613	Hansen et al. (2013); Zachos et al. (2008)
Pliocene	5,0	1,28806602	15,35978439	0,55182613	Hansen et al. (2013); Zachos et al. (2008)
Pliocene	5,0	1,28806602	15,35978439	0,55182613	Hansen et al. (2013); Zachos et al. (2008)
Pliocene	4,6	1,28806602	15,35978439	0,55182613	Hansen et al. (2013); Zachos et al. (2008)
Pliocene	4,0	1,28806602	15,35978439	0,55182613	Hansen et al. (2013); Zachos et al. (2008)
Pliocene	4,0	1,28806602	15,35978439	0,55182613	Hansen et al. (2013); Zachos et al. (2008)
Pliocene	3,9	1,28806602	15,35978439	0,55182613	Hansen et al. (2013); Zachos et al. (2008)
Pliocene	3,4	1,28806602	15,35978439	0,55182613	Hansen et al. (2013); Zachos et al. (2008)

Pliocene	3,3	1,28806602	15,35978439	0,55182613	Hansen et al. (2013); Zachos et al. (2008)
Pliocene	3,0	1,28806602	15,35978439	0,55182613	Hansen et al. (2013); Zachos et al. (2008)
Pliocene	3,0	1,28806602	15,35978439	0,55182613	Hansen et al. (2013); Zachos et al. (2008)
Pliocene	2,7	1,28806602	15,35978439	0,55182613	Hansen et al. (2013); Zachos et al. (2008)
Pliocene	2,0	1,28806602	15,35978439	0,55182613	Hansen et al. (2013); Zachos et al. (2008)
Pleistocene	1,5	-0,014927153	12,21572556	-50,83255763	Hansen et al. (2013); Zachos et al. (2008)
Pleistocene	1,0	-0,014927153	12,21572556	-50,83255763	Hansen et al. (2013); Zachos et al. (2008)
Pleistocene	1,0	-0,014927153	12,21572556	-50,83255763	Hansen et al. (2013); Zachos et al. (2008)
Pleistocene	0,1	-0,014927153	12,21572556	-50,83255763	Hansen et al. (2013); Zachos et al. (2008)

Appendix 4

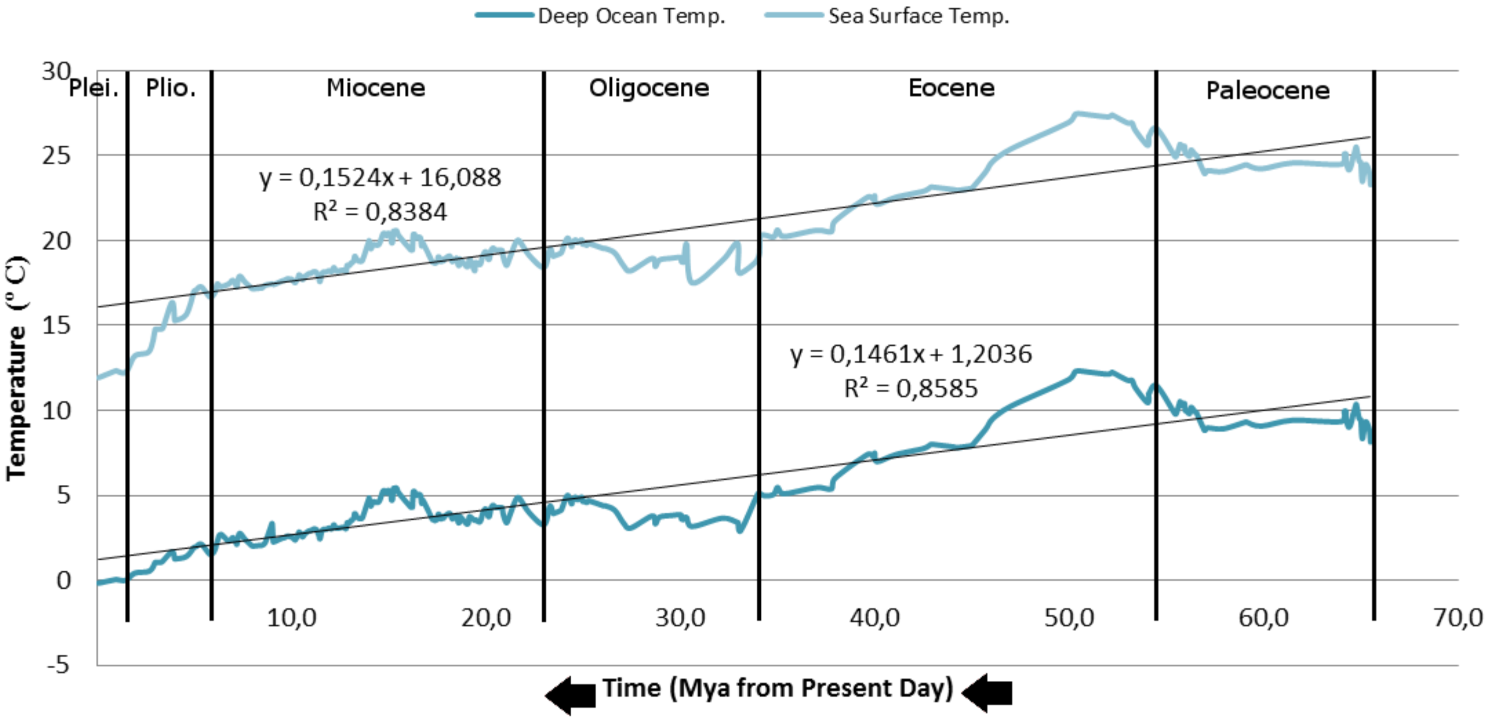

Figure 2: Sea surface temperature and deep ocean temperature through the Cenozoic age. **Sources:** Hansen et al. (2013) & Zachos et al. (2008)

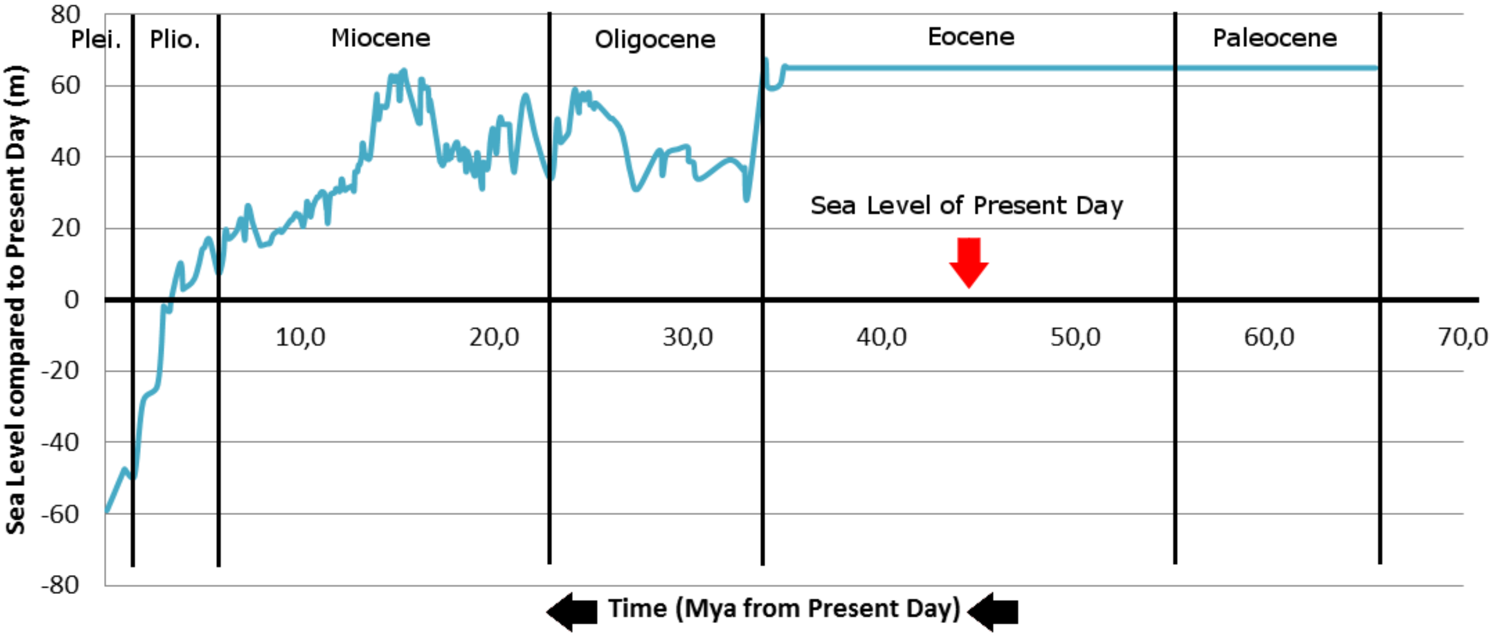

Figure 3: Diagram displaying how the global sea level (SL; m) have varied during the Cenozoic age (here ranging from 65,5 Mya at the start of the Paleocene (to the right) to 100000 years ago during the Pleistocene (Plei.; to the left)). **Sources:** Hansen et al. (2013) & Zachos et al. (2008)

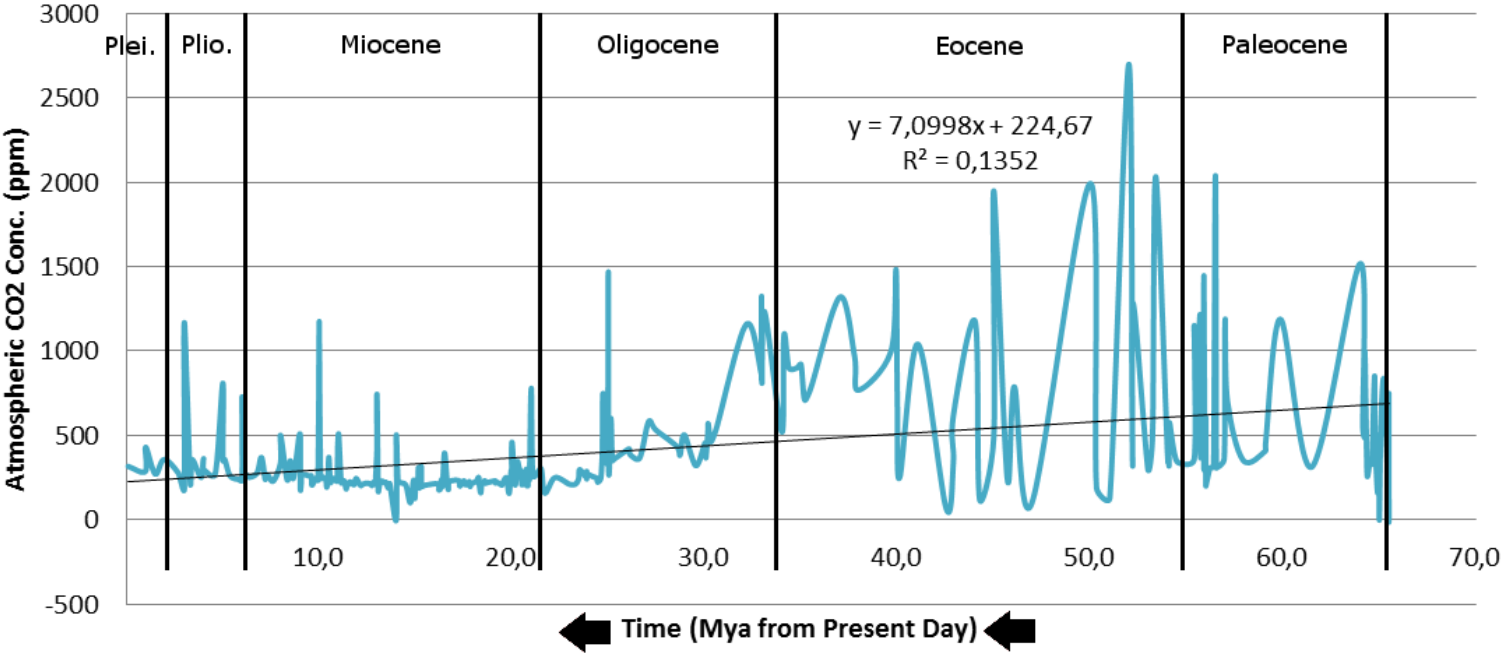

Figure 4: Diagram displaying how the global concentrations of atmospheric CO_2 (pCO_2; ppm) have varied during the Cenozoic age (here ranging from 65,5 Mya at the start of the Paleocene (to the right) to 100000 years ago during the Pleistocene (Plei.; to the left). **Source:** Royer (2006)

Data References

Below follows a list of all references used in the analysis as well as in Appendix 1a, 1b, 1c, 1d, 2, 3a, 3b & 4; including the major contributors of all species data from Fossilworks.org.

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For all references which following search is based on, see following files: EoceneArchaeplastida-refs.csv ***#1*** & EoceneArchaeplastida-refs.csv ***#2***

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